Appendix A

Biological and Hydraulic Design Criteria: As Modified by the Wynoochee Dam Technical Advisory Committee

BIOLOGICAL HYDRAULIC DESIGN CRITERIA

Wynoochee Dam Downstream Fish Passage Project

INTRO: Staff from the Washington Department of Fisheries and the National Marine Service provided criteria for hydraulic conditions to be met throughout the bypass system. These criteria were based on the environmental requirements of the fish which are to be passed through the system. The criteria are listed below:

1) **Eicher screen penstock discharge operating range = 210 to 800 cfs. Screen should function up to 800.**

2) **Penstock minimum diameter = 10.0 ft.**

3) **Eicher screen removable penstock section diameter = 10.0 ft.**

4) **Maximum average penstock flow velocity within removable Eicher screen penstock section during screen operation = 8.0 fps.**

5) **Bypass minimum average velocity to be 7 fps and bypass is to be 24 inch diameter pipe.**

6) **No light must enter the bypass transition upstream of the 24-inch diameter pressure pipe.**

7) **Pressure bypass pipe minimum diameter = 24 inches.**

8) **Pressure bypass pipe will be material smooth wall HDPE pipe or equivalent. Should have smooth surface, smooth joints, and is bendable. Minimum bend radius within pressure bypass pipe = 5 diameters.**

9) **Flow velocity normal to Eicher screen at any one point must not exceed 0.40 times the average upstream penstock velocity. Screen should be at a 16-19 degree orientation.**

10) **Fish bypass discharge during Eicher screen operation must be between 10 and 30 cfs.**

11) **Fish bypass pressure pipe average velocity must not exceed 10 fps. nor be less than 7 fps.**

12) **Free surface open channel flume or pipe flow velocity must not exceed 35 fps.**

13) **Hydraulic jumps are not permitted within the bypass system. There may be a jump at the END of the system, but all efforts to avoid this should be made.**

14) **Nominal Water depth within the open channel flume or free surface pipe flow must exceed 9 inches at all times.**

15) **Horizontal or vertical bends with radius less than 60 feet are not permitted within the high velocity free surface pipe or flume flow.**

16) **At no point will full pipe flow conditions be permitted within the free surface flow pipe, either as a result of excessive depth of water or as a result of air entrainment into the flow.**

17) **Viewing ports must be provided at strategic locations along any enclosed pipe with which free surface flow conditions are to be maintained.**

18) **In progress. Discharge of the bypassed flow into the river is to be effected through a spreading of flow such that no plunging singular jet is formed.**

19) **Maximum entrance jet total velocity of bypassed flow into the river must be less than 30 fps.**

20) **Bypass flow discharge must exit into a pool of water greater than five (5) feet in depth.**

Appendix B

Hydraulic Analysis

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HYDRAULIC ANALYSIS APPENDIX

The proposed Wynoochee Dam fish bypass facility is composed of numerous interrelated features. The 10% level design effort analyzed several alternatives for each of these features. Some level of hydraulic analysis, in support of the 10% level design effort, was required for each feature to ensure that it would function properly throughout the range of operating conditions that can be expected at the site. The following features were included in the hydraulic analysis:

- Eicher screen
- HDPE pressure bypass pipeline
- Multi-level discharge system
- Gravity flume

EICHER SCREEN

Due to the fact that the Eicher screen is a relatively new concept for fish screening applications, there is a limited amount of existing hydraulic data available. Eicher screen hydraulics have been previously studied and analyzed by others (Winchell, Fred C. et al, 1991; Adam, Pieter et al, 1991). The results of these studies were used in the development of the hydraulic and biological design criteria for the Wynoochee Dam application and were used as guidance in the hydraulic analysis of the Wynoochee Dam bypass system.

For the 10% level design of the Wynoochee Dam fish bypass facility, the analysis of the Eicher screen hydraulics was limited to determining the fluid forces acting on the screen under different operational flow rates and magnitudes of screen obstruction. The basis for this determination was the previous hydraulic evaluation of an Eicher screen installed at the Elwha Hydroelectric Project in Washington State (Adam, Pieter et al, 1991). This installation consisted of a screen installed in a 9-foot diameter penstock at an approximately 16-degree angle. The porosity configuration for the screen was 63% for the upstream 2/3 of the screen and 32% and 8% for the remainder. This was the same screen geometry and porosity configuration that was assumed for the Wynoochee Dam application.

Among other things, the studies of the Elwha Dam installation evaluated the head loss through the Eicher screen. Head loss was measured both in the field and in a physical model study. The measurements in the field indicated a maximum of 1.9 feet of head loss, and the maximum head loss that was measured in the physical model was 1.3 feet (Adam, Pieter et al, 1991). The average penstock velocities associated with these two magnitudes of maximum head loss were 7.5 fps and 8 fps for the field measurement and the physical model measurement, respectively. The study concluded that the difference in head loss between the full scale and the physical model measurements was likely attributed to the lack of seals and clamping bars in the physical model, and the required removal of wedge wire support u-clips in the physical model (Adam, Pieter et al, 1991). Figure 1 was copied from (Adam, Pieter et al, 1991), and graphically shows the results.

For the current analysis, head losses through the Eicher screen for velocities that exceeded those presented in Figure 1 were extrapolated, and hence should be considered approximate. The measured head losses, and the extrapolated head losses, were then used to estimate the fluid forces that would act on the screen installation at Wynoochee Dam. Forces acting on the screen surface were computed for both the clear screen (unobstructed flow) and the partially obstructed screen conditions. The partially obstructed conditions were defined as those conditions that would result in an increase of 2 feet of head loss through the screen. The results are presented in Table 1.

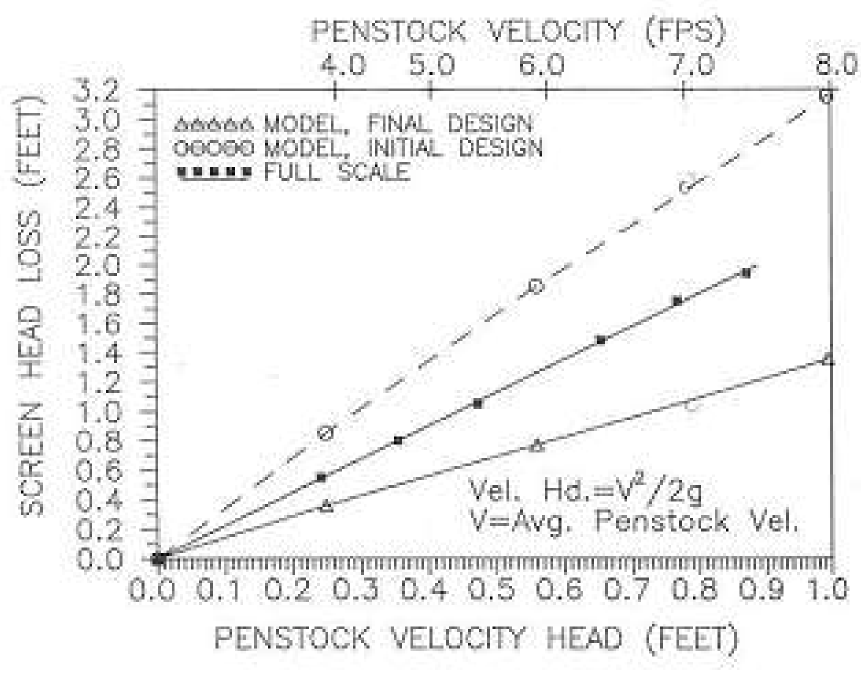

Figure 3 Full–Scale and Model Screen Head Loss

Figure 1. Full-Scale and Model Screen Head Loss Results for Elwha Dam Eicher Screen Installation (Adam, Pieter et al, 1991).

Table 1. Fluid Forces Acting on Eicher Screen							
		Clear Screen			Partially Obstructed Screen		
Q (cfs)	Penstock Velocity (fps)	Head Loss (ft)	Pressure Differential (psf)	Resultant Force (kips)	Head Loss (ft)	Pressure Differential (psf)	Resultant Force (kips)
600	7.6	2.2	138	38.2	4.2	262	72.5
800	10.2	4.0	250	69.3	6.0	370	103.6
1,300	16.6	10.7	670	185.0	12.7	790	219.4

PRESSURE BYPASS PIPELINE

A 24-inch diameter pressure bypass pipeline is proposed for construction from the Eicher screen vault to the multi-level discharge system. The length of this alignment is approximately 400 linear feet. High-density polyethylene (HDPE) pipe was the only pipe material considered for this application, due to the smooth interior surface that the material provides.

Due to the fact that the hydraulics of the pressure bypass pipeline are integrally related to and dependent on the hydraulics of the multi-level discharge system, the hydraulic analyses of these two features were combined. The assumptions, methodology, and conclusions of this hydraulic analysis are therefore described in the multi-level discharge system section of this appendix.

MULTI-LEVEL DISCHARGE SYSTEM

The need to operate the fish bypass facility through a range of possible reservoir pool elevations and a range of possible penstock flow rates required the development of a project feature that would provide operational flexibility during these changing hydraulic conditions. At the terminus of the pressure bypass pipe, prior to discharge to the gravity flume, a multi-level discharge system was proposed. This system is comprised of multiple pressure outlet pipes set at different elevations that will discharge to the gravity flume. The multi-level discharge system will allow for the single pressure bypass pipeline described above to be connected to one of the pressure outlet pipes. The decision as to which outlet pipe to connect to will be dependent on the reservoir pool elevation and the penstock flow rate at the time of operation.

Two multi-level discharge system alternatives were considered. Alternative 1 included a below grade vault where the incoming bypass pipe is routed to a different level outlet pipe, depending on the upstream reservoir and penstock flow rate. Alternative 2 proposed using valves and detachable pipe segments to divert the bypass flows into a specific outlet pipe. Refer to the main body of the report and the plan sheets in Appendix C for more detailed descriptions of the two alternatives.

For the hydraulic analysis, the main purpose was to determine the required number of outlet pipes necessary for each multi-level discharge system alternative, and the corresponding invert elevations of those outlet pipes, given the ranges of upstream reservoir elevations (800 feet to 760 feet) and penstock discharge rates (230 cfs to 800 cfs), and the design criteria for fish bypass.

Due to the interrelated nature of the bypass system, a spreadsheet model was set-up to analyze the hydraulics of the entire pressure system, using the reservoir pool elevation as the upstream boundary condition and assuming free discharge at the outlet to the gravity flume.

The spreadsheet model of hydraulic heads from the reservoir pool to the outlet pipe accounts for all hydraulic losses through the pressurized system. Head losses considered were friction loss through the 10-foot diameter penstock, entrance losses at the 24-inch diameter HDPE pipe inlet, friction losses through the 24-inch diameter HDPE pipe, and bend losses through the HDPE pipe. The head loss through the Eicher screen was not considered since the pressurized bypass pipe entrance to the HDPE pipe is located upstream of the screen element. A rounded configuration was assumed at the entrance to the HDPE pipeline. Friction losses were calculated using the Darcy-Weisbach equation. The viscosity of water was determined based on a water temperature of 20-degrees Celsius. The total length of the 24-inch bypass pipe is a variable, dependent on the specific outlet pipe of the multi-level discharge system that is in operation. Bend losses in the multi-level discharge system were also accounted for, and it was assumed that a radius of bend would be at least 5 times the diameter of pipe to meet the biological design criteria. Minor losses, such as pipe fitting losses, were not considered at this level of study, and were assumed to be a final design analytical element.

One of the critical biological design criteria was to maintain a magnitude of velocity in the HDPE bypass greater than that of the sweeping velocity along the face of the Eicher screen. This criterion was necessary so as to assure that fish do not resist entering the HDPE pipe, and to prevent injury to fish due to impingement on the screen surface. The sweeping velocity along the face of the Eicher screen was computed, knowing the average approach velocity in the penstock and the angle of inclination of the screen (16.5 degrees with respect to the penstock).

Another critical biological design criterion was the range of velocities that are allowed through the pressure bypass pipe during the fish migration window. The criterion states that bypass pipe will have approach velocities within the range of 7 fps to 10 fps (Criteria #5 and #11). Given that the diameter of the pressure pipe is 24-inches, these velocities correspond with a flow rate range of 22 cfs to 32 cfs.

The above two biological design criteria were the driving forces in determining the number of outlet pipes necessary for a given multi-level discharge system, because as the operating velocity in penstock increases (caused by a increased penstock flow rate), the allowable lower limit of discharge in the HDPE bypass also has to increase from initial 20 cfs, reducing the operable discharge range of the pipe. In order to determine the required number of outlet pipes for a given multi-level discharge system, rating curves were developed for different penstock discharge rates, assuming a 0.5 foot overlap between the lower flow rate and the upper flow rate of adjacent outlet pipes. Table 2 summarizes the number of multi-level discharge pipes required for specific penstock flow rates and multi-level discharge system alternatives.

Table 2. Required number of multi-level discharge outlet pipes for specific penstock flow rate.

		Flow in HDPE Bypass		Velocity in HDPE Bypass		Required Number of Outlet Pipes	
Penstock Q (cfs)	Penstock V (fps)	Upper Limit (cfs)	Lower Limit (cfs)	Upper Limit (fps)	Lower Limit (fps)	Alt 1	Alt 2
230	2.81	35	20	11.14	6.37	5	6
400	4.88	35	20	11.14	6.37	5	6
520	6.35	35	20	11.14	6.37	5	6
600	7.32	35	23	11.14	7.32	6	7
650	7.94	35	25	11.14	7.96	7	8
800	9.77	35	30.5	11.14	9.71	N.A.	18

As shown in Table 2, as the assumed operating flow rate through the penstock increases, the operable range that the HDPE bypass is capable of operating within (given the constraints of the two aforementioned biological design criteria) decreases, thus requiring more outlet pipes. Alternative 2 requires more outlet pipes that Alternative 1 due to the fact that there is slightly less head loss in the Alternative 2 multi-level discharge system. This smaller amount of head loss results in a smaller range of reservoir levels that a specific outlet pipe can remain in operation before it is necessary to switch to the next outlet pipe.

The results of this hydraulic analysis were compared to the previous hydraulic analysis performed by others (Harza Northwest, 1997). Harza’s calculations determined that five outlet pipes would be required, which is comparable to the results presented in Table 2. However, comparison between the Table 2 results and results of Harza’s analysis should be done so with caution. It appears that Harza’s calculations didn’t strictly adhere to the biological design criteria that the flow velocity in the bypass is always to be faster than that of penstock to attract the fish.

Based on the results presented in Table 2, the assumption was made that the maximum flow rate that could be allowed through the penstock during the fish migration window would have to be 600 cfs, which results in six required outlet pipes for Alternative 1 and seven required outlet pipes for Alternative 2. Due to the larger number of outlet pipes that are required for penstock flows greater than 600 cfs, this conclusion was based on construction cost considerations. This conclusion does, however, violate Criterion #1 (Appendix A) which states that the Eicher screen penstock discharge operational range should be 210 to 800 cfs, and that the screen should function up to 800 cfs. However, in discussions with the Corps, it was decided that this was a realistic assumption that was still consistent with other criteria (Criterion #4).

Tacoma Public Utilities (TPU) has the capability to control the flows through the penstock during the fish passage window, by allowing excess flows to pass through the lower outlets of the dam, thereby bypassing the penstock. TPU therefore has some flexibility to limit the flow through the penstock during the fish migration window to a maximum specified flow of 600 cfs.

Based on the results presented in Table 2, the proposed multi-level discharge system will include six (6) outlet pipes for Alternative 1 and seven (7) outlet pipes for Alternative 2. The anticipated range of flows through the HDPE bypass pipeline will be between 23 and 35 cfs, when the penstock is flowing at 600 cfs. Table 3 summarizes the design outlet elevations of the outlet pipes and the respective range of reservoir water surface elevations that each outlet pipe will operate within.

Rating curves for each of the outlet pipes in Alternative 1 and Alternative 2 were also generated, and are shown as Figure 1 and 2, respectively. For illustrative purposes, the rating curves were extended beyond the upper and lower bypass flow rate limits.

Table 3. Hydraulic summary of multi-level discharge pipes for Alternatives 1 and 2 assuming a 600 cfs flow rate in the penstock

Outlet Pipe Number	Alternative 1			Alternative 2		
	Invert Elev. (ft)	Approximate Reservoir WSE (ft) min (Q=23)	(ft) max (Q=35)	Invert Elev. (ft)	Approximate Reservoir WSE (ft) min (Q=23)	(ft) max (Q=35)
Pipe # 1	783.38	791.40	800.00	784.84	792.23	800.00
Pipe # 2	776.90	784.22	791.90	779.19	785.88	792.73
Pipe # 3	770.38	777.42	784.72	773.48	779.89	786.36
Pipe # 4	764.15	770.94	777.92	768.08	774.24	780.39
Pipe # 5	758.33	764.84	771.44	763.09	768.96	774.74
Pipe # 6	752.70	759.00	765.34	758.29	763.96	769.46
Pipe # 7	N.A	N.A	N.A	753.29	758.96	764.46

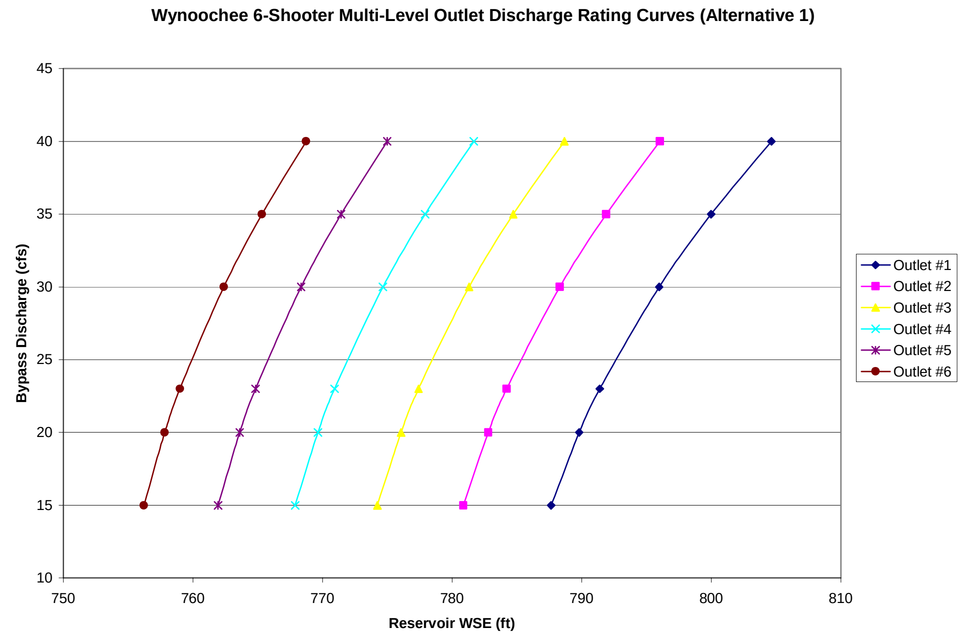

Figure 1. Operational curves for the six outlet pipes for Alternative 1 of the multi-level discharge system.

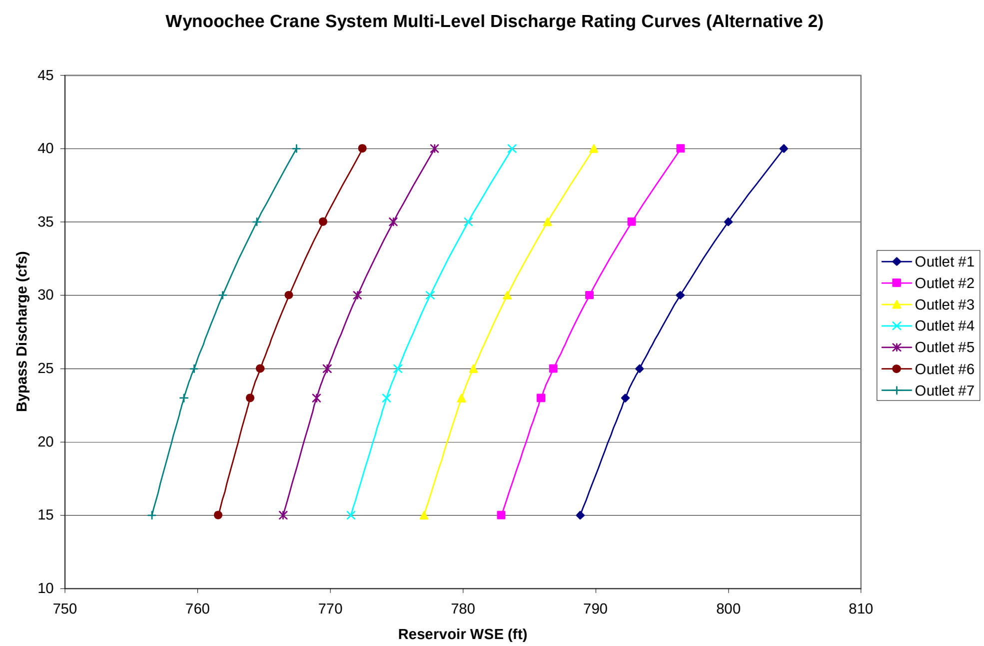

Figure 2. Operational curves for the seven outlet pipes for Alternative 2 of the multi-level discharge system.

GRAVITY FLUME

A gravity flume is proposed to start at the outlet of the multi-level discharge system and terminate at the proposed transitional ponds, located in the vicinity of the existing hydroelectric facility substation. The approximate length of the alignment is 1,800 linear feet.

The flume will be designed so that supercritical flow (Froude No. > 1.1) would be maintained throughout the open flume section, and that no hydraulic jump would occur within the flume section. If necessary, a hydraulic jump is allowed at the outlet of the flume.

Since the horizontal and vertical alignment of the flume will be refined and finalized once new topographic surveys are completed, a table of hydraulic parameters for various flume slopes and flume flow rates was generated. Therefore, instead of an open channel steady state hydraulic model, normal depth calculations were developed for each of the flume slopes and flow rates.

Manning's n of 0.010 was used, based on the fact the flume will be either lined with a synthetic coating system or will be constructed with a smooth material such as fiberglass or aluminum. The cross-section of the flume is a semi-circular invert, trapezoidal side slopes up to 2 feet of a total water depth, and vertical walls next 1 foot up to the top, resulting a 3 feet of total cross-sectional depth. Refer to Plan Sheet 21 in Appendix C for a cross section detail of the flume.

For a given flume slope and flow rate, the minimum bend radius necessary to keep the superelevation of water at the outside of the bend at least 1 foot below the top of the open flume was determined using the USACE's Hydraulic Design of Flood Control Channel manual. In Table 4, the water depth and other hydraulic parameters for specific flume slopes and flow rates are presented, along with the minimum design radius of the bend.

The results presented in Table 4 were used to develop the horizontal and vertical alignments of the gravity flume for the 10% design. Based on these results, the minimum gradient of the gravity flume should be 0.020 (ft/ft) in order to maintain supercritical flow for the entire range of flows expected through the flume. It is recommended that the Froude number for the design flow be maintained above a value of 1.5 throughout the flume alignment, thereby ensuring that the supercritical flow regime is stable. Secondly, the flume gradient should not be any steeper than 0.190 ft/ft, so as to maintain the minimum allowable flow depth of 9 inches (Criteria #14). Finally, the flume gradient should not be any steeper than 0.190 ft/ft so that the maximum average velocity in the flume will be less than 35 ft/s (Criteria #12).

Table 4. Hydraulic Parameters for Gravity Flume										
	20 cfs Open Channel Flow Rate					35 cfs Open Channel Flow Rate				
Slope (ft/ft)	**Flow Depth (ft)**	**Hydraulic Depth (ft)**	**Average Velocity (fps)**	**Froude No.**	**Minimum Radius* (ft)**	**Flow Depth (ft)**	**Hydraulic Depth (ft)**	**Average Velocity (fps)**	**Froude No.**	**Minimum Radius* (ft)**
0.005	2.03	1.38	7.28	1.09	N.A	2.81	2.17	8.13	0.97	N.A
0.01	1.69	1.14	9.55	1.58	17	2.28	1.63	10.77	1.49	N.A
0.02	1.40	0.97	12.54	2.25	13	1.89	1.26	14.14	2.22	N.A
0.03	1.26	0.88	14.70	2.77	14	1.70	1.15	16.58	2.73	52
0.04	1.16	0.82	16.45	3.21	15	1.57	1.07	18.56	3.16	44
0.05	1.09	0.77	17.95	3.60	16	1.48	1.02	20.26	3.54	42
0.06	1.04	0.74	19.27	3.96	17	1.41	0.98	21.77	3.89	41
0.07	0.99	0.71	20.46	4.29	18	1.35	0.93	23.12	4.21	41
0.08	0.96	0.68	21.56	4.60	19	1.30	0.91	24.36	4.51	42
0.09	0.93	0.66	22.56	4.88	20	1.26	0.88	25.52	4.79	43
0.10	0.90	0.64	23.50	5.16	21	1.23	0.86	26.59	5.06	44
0.11	0.88	0.63	24.39	5.42	21	1.20	0.84	27.60	5.32	45
0.12	0.86	0.61	25.22	5.67	22	1.17	0.83	28.56	5.56	46
0.13	0.84	0.60	26.02	5.91	23	1.14	0.80	29.46	5.79	46
0.14	0.82	0.59	26.77	6.14	24	1.12	0.79	30.33	6.02	47
0.15	0.80	0.58	27.49	6.37	25	1.10	0.77	31.16	6.24	49
0.16	0.79	0.57	28.18	6.59	26	1.08	0.76	31.95	6.45	50
0.17	0.78	0.56	28.85	6.80	26	1.06	0.75	32.72	6.66	50
0.18	0.77	0.55	29.49	7.00	27	1.04	0.74	33.46	6.85	51
0.19	0.75	0.54	30.11	7.20	28	1.03	0.73	34.17	7.05	52

* Minimum radius is the required radius of bend to maintain 12-inches of freeboard, including the effect of superelevation

REFERENCES

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Chow, Ven Te. Open Channel Hydraulics. McGraw Hill Book Company. 1959

United States Army Corps of Engineers (USACE). Hydraulic Design of Flood Control Channels, EM 1110-2-1601. 1994

Appendix C

10% Plan Sheets

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Appendix D

10% Cost Estimates

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Intake Structure Modifications - Alternative 1								
Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	Mobilization/Demobilization	LS	1			$1,000.00	$1,000	
2	Install permanent attraction lighting	LS	1			$10,000.00	$10,000	
3	Fill Temporary Access Hole	CY	4	$1,000	$150.00	$1,150.00	$4,600	
4	Remove Temporary Baffles and Gate	LS	1	$500		$500.00	$500	
	Construction Subtotal						$16,100	
	Contingency	35%					$5,635	
	Estimated Construction Cost						**$21,735**	
	Planning Engineering and Design	15%					$3,260	
	S&A	12%					$2,608	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$27,603**	
	Annual Operation and Maintenance	2%					$435	

Intake Structure Modifications - Alternative 2								
Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	Mobilization/Demobilization	LS	1			$5,000	$5,000	
2	Install permanent attraction lighting	LS	1		$10,000	$10,000	$10,000	
3	Hydraulic Hoist and Controls	LS	1		$60,000	$60,000	$60,000	
4	Upper portal improvements	LS	1		$5,000	$5,000	$5,000	
5	Upper fish passage baffle	LS	1	$15,000	$5,000	$20,000	$20,000	
6	Lower fish passage baffle	LS	1	$15,000	$4,000	$19,000	$19,000	
7	Penstock transition concrete	LS	1	$10,000	$1,000	$11,000	$11,000	
8	Control system modifications	LS	1		$10,000	$10,000	$10,000	
	Construction Subtotal						$140,000	
	Contingency	35%					$49,000	
	Estimated Construction Cost						**$189,000**	
	Planning Engineering and Design	15%					$28,350	
	S&A	12%					$22,680	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$240,030**	
	Annual Operation and Maintenance	2%					$3,780	

Eicher Screen Alternative 1 - Eicher Screen with Penstock Bypass								
Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	Selective 10' dia. Exst. Pipe Removal	LS	1			$14,700.00	$14,700	
2	Rock Excavation	CY	7800			$40.00	$312,000	
3	Excavation	CY	2450			$20.00	$49,000	
4	12" thick Conc. Vault wall	CY	300			$500.00	$150,000	
5	24" thick Conc. Vault Base Mat	CY	500			$300.00	$150,000	
6	10' dia. Pipe	LF	200			$1,500.00	$300,000	
7	10' dia. 45 degree Wye	EA	2	$16,000	$25,000.00	$41,000.00	$82,000	
8	10' dia 45 degree Elbow	EA	2	$8,000	$9,200.00	$17,200.00	$34,400	
9	10' dia. Knife Gate Valve w/ Electric Motor Actuator	EA	1	$150,000	$300,000.00	$450,000.00	$450,000	
10	10' dia. PVC Plug	EA	1		$10,000.00	$10,000.00	$10,000	
11	10' dia. Victaulic Coupling	EA	2	$1,000	$2,000.00	$3,000.00	$6,000	
12	Blind Flange	EA	2	$500	$1,500.00	$2,000.00	$4,000	
13	Spool Support Structure with Rail	LS	1			$30,000.00	$30,000	
14	Spool Moving Mechanism	LS	1			$30,000.00	$30,000	
15	Eicher Screen in Pipe	EA	1			$150,000.00	$150,000	
16	Flexible Coupling for Eicher Screen	EA	2			$6,000.00	$12,000	
17	Eicher Screen Operating Mechanism	EA	1			$50,000.00	$50,000	
18	Walkway w/Stairs	LS	1			$20,000.00	$20,000	
19	6-foot high security fence	LF	400			$22.00	$8,800	
20	Floor Drain w/ 12" dia. 180' pipe	LF	180			$60.00	$10,800	
21	Controls and Instrumentation	LS	1			$15,000.00	$15,000	
22	Power and Telemetry	LS	1			$50,000.00	$50,000	
	Construction Subtotal						$1,938,700	
	Contingency	35%					$678,545	
	Estimated Construction Cost						**$2,617,245**	
	Planning Engineering and Design	15%					$392,587	
	S&A	12%					$314,069	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$3,323,901**	
	Annual Operation and Maintenance	2%					$52,345	

Eicher Screen Alternative 2 - Eicher Screen with Penstock Bypass

Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	Selective 10' dia. Exst. Pipe removal	LS	1			$14,700.00	$14,700	
2	Rock Excavation	CY	4000			$40.00	$160,000	
3	Excavation	CY	1060			$20.00	$21,200	
4	12" thick Conc. Vault wall	CY	300			$500.00	$150,000	
5	24" thick Conc. Vault base mat	CY	400			$300.00	$120,000	
6	10' dia. Pipe	LF	200			$1,500.00	$300,000	
7	10' dia. 45degree Wye	EA	2	$16,000	$25,000.00	$41,000.00	$82,000	
8	10' dia 45 degree elbow	EA	2	$8,000	$9,200.00	$17,200.00	$34,400	
9	Rectangular Wye w/ 3 Transitions	LS	1			$60,000.00	$60,000	
10	Rectangular 10'x10' swing gate	EA	1			$20,000.00	$20,000	
11	Swing Gate actuating mechanism	LS	1			$30,000.00	$30,000	
12	Eicher Screen	EA	1			$150,000.00	$150,000	
13	Eicher Screen Operating Mechanism	LS	1			$50,000.00	$50,000	
14	Flexible Couplings for Eicher Screen	EA	2			$6,000.00	$12,000	
15	Walkway w/Stairs	LS	1			$30,000.00	$30,000	
16	6-foot high security fence	LF	400			$22.00	$8,800	
17	Floor Drain w/ 12" dia. 180' pipe	LF	360			$60.00	$21,600	
18	Controls and Instrumentation	LS	1			$15,000.00	$15,000	
19	Power and Telemetry	LS	1			$50,000.00	$50,000	
	Construction Subtotal						$1,329,700	
	Contingency	35%					$465,395	
	Estimated Construction Cost						**$1,795,095**	
	Planning Engineering and Design	15%					$269,264	
	S&A	12%					$215,411	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$2,279,771**	
	Annual Operation and Maintenance	2%					$35,902	

Eicher Screen Alternative 3 - Eicher Screen with Replaceable Penstock Section								
Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	Selective 10' dia. Exst. Pipe removal	LS	1			$15,000.00	$15,000	
2	Rock Excavation	CY	2650			$40.00	$106,000	
3	Excavation	CY	850			$20.00	$17,000	
4	12" thick Conc. Vault wall	CY	180			$500.00	$90,000	
5	24" thick Conc. Vault base mat	CY	300			$300.00	$90,000	
6	10' dia. Pipe	LF	75			$1,500.00	$112,500	
7	Eicher Screen	EA	1			$150,000.00	$150,000	
8	Eicher Screen Operating Mechanism	LS	1			$50,000.00	$50,000	
9	Eicher Screen Support Structure w/ Rail	LS	1			$120,000.00	$120,000	
10	Eicher Screen Section Moving Systems	LS	1			$60,000.00	$60,000	
11	Flexible Couplings for Eicher Screen	EA	2			$6,000.00	$12,000	
12	Walkway w/Stairs	LS	1			$20,000.00	$20,000	
13	6-foot high security fence	LF	230			$22.00	$5,060	
14	Floor Drain w/ 12" dia. 180' pipe	LF	180			$60.00	$10,800	
15	Controls and Instrumentation	LS	1			$15,000.00	$15,000	
16	Power and Telemetry	LS	1			$50,000.00	$50,000	
	Construction Subtotal						$923,360	
	Contingency	35%					$323,176	
	Estimated Construction Cost						**$1,246,536**	
	Planning Engineering and Design	15%					$186,980	
	S&A	12%					$149,584	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$1,583,101**	
	Annual Operation and Maintenance	2%					$24,931	

Pressure Bypass Pipeline								
Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	24 Inch diameter HDPE pipe (incl.excavation and b	LF	440			$220.00	$96,800	
2	36 Inch diameter steel casing for bridge crossing	LF	180			$350.00	$63,000	
3	Access ports	Each	2			$10,000.00	$20,000	
4	Bridge Support @ 10' -0"	Each	18			$500.00	$9,000	
5	Controls and Instrumentation	LS	1			$5,000.00	$5,000	
6	Power and Telemetry	LS	1			$20,000.00	$20,000	
	Construction Subtotal						$213,800	
	Contingency	35%					$74,830	
	Estimated Construction Cost						**$288,630**	
	Planning Engineering and Design	15%					$43,295	
	S&A	12%					$34,636	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$366,560**	
	Annual Operation and Maintenance	2%					$5,773	

Multi-Level Flume Discharge Alternative 1 - "Six Shooter"								
Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	24 Inch Diameter Discharge Pipe	LF	1040			$200.00	$208,000	
2	Shut off valve (ball valve) for switch over	Each	1			$50,000.00	$50,000	
3	U-shaped sweeps	Each	6			$10,000.00	$60,000	
4	Clearing and Grading for Flume and discharge pipe	LS	1			$20,000.00	$20,000	
5	Concrete Flume	LF	300			$500.00	$150,000	
6	Rock excavation for vault	CY	1600			$40.00	$64,000	
7	Excavation for vault	CY	2000			$20.00	$40,000	
8	Concrete vault 12"thick wall	CY	170			$500.00	$85,000	
9	Concrete vault 12"thick base mat	CY	125			$300.00	$37,500	
10	Trench drain	LS	1			$8,000.00	$8,000	
11	6-foot high security fence	LF	150			$22.00	$3,300	
12	Grating, Grating Support and Guardrails in vault	SF	1350			$50.00	$67,500	
13	Piping and pipe supports in vault	LS	1			$48,000.00	$48,000	
14	Trail Relocation	LF	400			$80.00	$32,000	
15	18-inch drain pipe including excavation and backfill	LF	200			$60.00	$12,000	
16	Controls and Instrumentation	LS	1			$5,000.00	$5,000	
17	Power and Telemetry	LS	1			$20,000.00	$20,000	
	Construction Subtotal						$910,300	
	Contingency	35%					$318,605	
	Estimated Construction Cost						**$1,228,905**	
	Planning Engineering and Design	15%					$184,336	
	S&A	12%					$147,469	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$1,560,709**	
	Annual Operation and Maintenance	2%					$24,578	

Multi-Level Flume Discharge Alternative 2 - Removable U-Shaped Sweeps

Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	24 Inch Diameter Discharge Header Pipe	LF	350			$200.00	$70,000	
2	U-shaped sweeps	Each	7			$9,000.00	$63,000	
3	Clearing and Grading for Flume and discharge head	LS	1			$20,000.00	$20,000	
4	Concrete Flume	LF	300			$500.00	$150,000	
5	Shut off valve (ball valve) for switch over	Each	1			$50,000.00	$50,000	
6	Six inch drain line and valve	Each	7			$4,000.00	$28,000	
7	Crane sets for swap out of spool and u-shaped swee	Each	6			$3,000.00	$18,000	
8	Crane Support Structure	Each	6			$10,000.00	$60,000	
9	Crane Support Structure Foundation	Each	6			$22,500.00	$135,000	
10	Trail Relocation	LF	400			$80.00	$32,000	
11	Controls and Instrumentation	LS	1			$5,000.00	$5,000	
12	Power and Telemetry	LS	1			$20,000.00	$20,000	
	Construction Subtotal						$651,000	
	Contingency	35%					$227,850	
	Estimated Construction Cost						**$878,850**	
	Planning Engineering and Design	15%					$131,828	
	S&A	12%					$105,462	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$1,116,140**	
	Annual Operation and Maintenance	2%					$17,577	

Gravity Flume Alternative 1 - Concrete

Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	At grade flume	LF	1285			$400.00	$514,000	
2	Under ground flume (access road crossings)	LF	400			$1,000.00	$400,000	
	Construction Subtotal						$914,000	
	Contingency	35%					$319,900	
	Estimated Construction Cost						**$1,233,900**	
	Planning Engineering and Design	15%					$185,085	
	S&A	12%					$148,068	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$1,567,053**	
	Annual Operation and Maintenance	2%					$24,678	

Gravity Flume Alternative 2 - Fiberglass

Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	At grade flume	LF	1285			$660.00	$848,100	
2	Under ground flume (access road crossings)	LF	400			$1,260.00	$504,000	
	Construction Subtotal						$1,352,100	
	Contingency	35%					$473,235	
	Estimated Construction Cost						**$1,825,335**	
	Planning Engineering and Design	15%					$273,800	
	S&A	12%					$219,040	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$2,318,175**	
	Annual Operation and Maintenance	2%					$36,507	

Gravity Flume Alternative 3 - Aluminum

Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	At grade flume	LF	1285			$500.00	$642,500	
2	Under ground flume (access road crossings)	LF	400			$1,100.00	$440,000	
	Construction Subtotal						$1,082,500	
	Contingency	35%					$378,875	
	Estimated Construction Cost						**$1,461,375**	
	Planning Engineering and Design	15%					$219,206	
	S&A	12%					$175,365	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$1,855,946**	
	Annual Operation and Maintenance	2%					$29,228	

Discharge Outlet System - Alternative 2								
Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	Clearing and Grubbing	LS	1			$10,000.00	$10,000	
2	Underground Road Crossing	LF	50			$200.00	$10,000	
3	Swale Regrading	LF	250			$150.00	$37,500	
4	Discharge channel with log weirs	LF	100			$250.00	$25,000	
5	Modifiy existing sedimentation pond	LS	1			$40,000.00	$40,000	
6	Overflow pipe and screen	LF	150			$150.00	$22,500	
7	Excavation for Primary Pond	CY	70	$15	$5.00	$20.00	$1,400	
8	Excavation for Collection Channel	CY	90	$15	$5.00	$20.00	$1,800	
9	Landscaping	LS	1			$5,000.00	$5,000	
	Construction Subtotal						$153,200	
	Contingency	35%					$53,620	
	Estimated Construction Cost						**$206,820**	
	Planning Engineering and Design	15%					$31,023	
	S&A	12%					$24,818	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$262,661**	
	Annual Operation and Maintenance	2%					$4,136	

Test Facilities - Alternative 1 (Fish Screen and Crowder)

Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	Mobilization/Demobilization	LS	1			$15,000.00	$15,000	
2	Dewatering	LS	1			$5,000.00	$5,000	
3	Silt Fencing	LF	300			$6.20	$1,860	
4	Excavation	CY	200			$32.00	$6,400	
5	Structure Backfill	CY	50			$35.00	$1,750	
6	Gravel Base Material	TON	80			$25.00	$2,000	
7	Structure Concrete	CY	45			$350.00	$15,750	
8	Crowder Rail and Track	LF	80			$50.00	$4,000	
9	Crowder Rollers	EA	4			$250.00	$1,000	
10	Screen Hinges	EA	8			$125.00	$1,000	
11	Support Girders	LF	80			$20.00	$1,600	
12	Bridge Platform	SF	45			$30.00	$1,350	
13	Metal Handrails	LF	25			$50.00	$1,250	
14	Screen	EA	2			$750.00	$1,500	
15	Variable Speed Motor	EA	1			$500.00	$500	
16	Dipping Nets	EA	2			$50.00	$100	
	Construction Subtotal						$60,060	
	Contingency	35%					$21,021	
	Estimated Construction Cost						**$81,081**	
	Planning Engineering and Design	15%					$12,162	
	S&A	12%					$9,730	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$102,973**	
	Annual Operation and Maintenance	2%					$1,622	

Test Facilities - Alternative 2 (Trap Net)

Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	Hoop net	1	Ea			$130	$130	
2	Wing net 1/4" delta netting, 4' deep	1	Ea			$40	$40	
3	Wing attachment	1	Ea			$12	$12	
4	Net coat treatment	1	LS			$25	$25	
5	Shipping	1	LS			$40	$40	
6	Installation/Training	1	LS			$2,000	$2,000	
	Construction Subtotal						$2,247	
	Contingency	35%					$786	
	Estimated Construction Cost						**$3,033**	
	Planning Engineering and Design	15%					$455	
	S&A	12%					$364	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$3,852**	
	Annual Operation and Maintenance	2%						

Supplementation Ponds Alternative 1 - Concrete Ponds								
Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	8-inch Supply Pipe	LF	1200	$25	$25.00	$50.00	$60,000	
2	Packed Column Degassing Units	EA	2	$2,000	$3,000.00	$5,000.00	$10,000	
3	Duplex Pumpstation - 1000 gpm, (include Electrica	LS	1	$30,000	$40,000.00	$70,000.00	$70,000	
4	Pond Excavation	CY	200	$15	$5.00	$20.00	$4,000	
5	Select Fill Foundation	CY	50	$5	$20.00	$25.00	$1,250	
6	Supply Header	EA	2	$2,000	$2,000.00	$4,000.00	$8,000	
7	Center Channel	LF	120	$25	$25.00	$50.00	$6,000	
8	Outlet Structure with Screens and Stop Logs	EA	2	$8,000	$2,000.00	$10,000.00	$20,000	
9	Overhead Bird Netting and Supports	LS	1	$10,000	$10,000.00	$20,000.00	$20,000	
10	8-inch Outfall Pipe, Deep Trench	LF	400	$35	$25.00	$60.00	$24,000	
11	6-inch Concrete Pond Bottom	CY	40	$250	$50.00	$300.00	$12,000	
12	8-inch Conc Pond Walls	CY	35	$500	$60.00	$560.00	$19,600	
13	Perimeter Fencing	LF	400	$5	$5.00	$10.00	$4,000	
14	Automatic Fish Counters -(2) in Manhole	LS	1	$5,000	$20,000.00	$25,000.00	$25,000	
	Construction Subtotal						$283,850	
	Contingency	35%					$99,348	
	Estimated Construction Cost						**$383,198**	
	Planning Engineering and Design	15%					$57,480	
	S&A	12%					$45,984	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$486,661**	
	Annual Operation and Maintenance	2%					$7,664	

Supplementation Ponds Alternative 2 - Plastic Lined Ponds

Item No.	Description	Unit	Total Project Quantity	Labor Unit Cost	Material Unit Cost	Total Unit Cost	Total Project Cost	Remarks
1	8-inch Supply Pipe	LF	1200	$25	$25.00	$50.00	$60,000	
2	Packed Column Degassing Units	EA	2	$2,000	$3,000.00	$5,000.00	$10,000	
3	Duplex Pumpstation - 1000 gpm, (include Electrica	LS	1	$30,000	$40,000.00	$70,000.00	$70,000	
4	Pond Excavation	CY	200	$15	$5.00	$20.00	$4,000	
5	Select Fill Foundation with Sand Top Course	CY	50	$10	$25.00	$35.00	$1,750	
6	Supply Header	EA	2	$2,000	$2,000.00	$4,000.00	$8,000	
7	Center Channel	LF	120	$25	$25.00	$50.00	$6,000	
8	Outlet Structure with Screens and Stop Logs	EA	2	$8,000	$2,000.00	$10,000.00	$20,000	
9	Overhead Bird Netting and Supports	LS	1	$10,000	$10,000.00	$20,000.00	$20,000	
10	8-inch Outfall Pipe, Deep Trench	LF	400	$35	$25.00	$60.00	$24,000	
11	60 mil Reinforced Plastic Liner	SY	400	$5	$5.00	$10.00	$4,000	
12	Liner Attachment to Conc	LF	160	$40	$10.00	$50.00	$8,000	
13	Woody Debris	LS	1	$1,000	$3,000.00	$4,000.00	$4,000	
14	Cobbles for Pond Bottom	CY	30	$10	$20.00	$30.00	$900	
15	Shade Trees or Camo-Netting at Pond Edges	LS	1	$3,000	$8,000.00	$11,000.00	$11,000	
16	Perimeter Fencing	LF	400	$5	$5.00	$10.00	$4,000	
17	Automatic Fish Counter- (2) in Manhole	LS	1	$5,000	$20,000.00	$25,000.00	$25,000	
	Construction Subtotal						$280,650	
	Contingency	35%					$98,228	
	Estimated Construction Cost						**$378,878**	
	Planning Engineering and Design	15%					$56,832	
	S&A	12%					$45,465	
	Real Estate Costs							
	Preliminary Alternative Cost Estimate						**$481,174**	
	Annual Operation and Maintenance	2%					$7,578	

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Appendix E

Preliminary Geotechnical Engineering Report

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Report

Preliminary Geotechnical Engineering Services

Wynoochee Dam Fish Passage

Grays Harbor Country, Washington

December 26, 2002

For

Tetra Tech Inc.

GeoEngineers

December 26, 2002

Consulting Engineers
and Geoscientists

Tetra Tech Inc.
1925 Post Alley
Seattle, Washington 98101

Attention: Harry Gibbons, Ph.D.

Report
Preliminary Geotechnical Engineering Services
Wynoochee Dam Fish Passage
Grays Harbor County, Washington
File No. 0371-090-00

INTRODUCTION

This report presents the results of our preliminary geotechnical engineering services for the proposed fish passage project at the Wynoochee Dam located on the Wynoochee River in Grays Harbor County, Washington. Our services have been completed in general accordance with the Tetra Tech Subconsultant Professional Services Agreement dated November 25, 2002.

The fish passage project will require installation of a fish screen and bypass pipeline/flume to reduce the smolt mortality rate and avoid periods of downtime for the generation facility. The project will include modifications to the intake at the penstock, installation of an Eicher screen in the penstock pipeline, and construction of a bypass pipeline, distribution vault, gravity flume, and open channel to transport the smolt to the Wynoochee River below the dam and powerhouse.

SCOPE

The purpose of our services is to review existing geologic studies and design reports for the Wynoochee Dam project, complete a site visit, and provide an opinion regarding the level of additional geotechnical studies that may be necessary for final design. Our specific scope of services therefore includes the following tasks:

1. Review existing geologic studies and design reports provided by the Corps of Engineers and Tetra Tech, Inc. This includes review of geologic mapping available in our files for the project area.
2. Complete a site visit and perform a preliminary geologic reconnaissance along the alignment proposed for the improvements.
3. Attend one design team meeting to present the results of our review and site visit, and discuss design issues.
4. Prepare a letter summarizing the results of our review and preliminary evaluation of the site conditions, along with general conclusions of geotechnical design issues.

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Our scope of services does not include developing final design recommendations for foundations, pipeline support or other improvements. The level of study requested at this time is to be sufficient to determine if adequate geotechnical information is available to support final design development.

SITE DESCRIPTION

REGIONAL GEOLOGY

We reviewed information in our files and available geologic mapping for the project area including the following:

- "Geologic Map of the Olympic Peninsula, Washington", United States Geologic Survey (USGS) Map I-994 dated 1988
- "Geology of the Pacific Northwest" by W.N. Orr and E.L. Orr, 2002

Our review of the available geologic information indicates subsurface conditions in the Lake Wynoochee area include basalt bedrock and overlying deposits that resulted from episodes of alpine glaciation. The glacial processes included scour by the glaciers, deposition of glacial and non-glacial sediments, and post-glacial deposition and erosion. The soils in the project area within the Wynoochee Valley are mapped by the USGS as deposits of the Olympic alpine glaciers that include unsorted glacial deposits (till) and stratified deposits of sand, gravel silt and clay. The mapped deposits include moraines and high river terraces along the major rivers that may not be directly related to the glaciation. The mapped surface soils also include river alluvium from the Wynoochee River that consists of sand, gravel, and silt. The surface soils at the project location are underlain by basalt bedrock.

We also reviewed the following maps and studies that were provided by the Corps of Engineers and Tetra Tech, Inc.:

- "Reservoir Geology, Wynoochee Lake, Washington" by U.S. Army Corps or Engineers dated October 18, 1972.
- "Design Geotechnical Report, Wynoochee Hydroelectric Project, Grays Harbor County, Washington" by Converse Consultants NW dated February 11, 1991.
- "Wynoochee Dam Exploratory Drilling Program Summary" by Carr Associates dated November 8, 1991.
- "Penstock Profile" by City of Tacoma Department of Public Utilities dated October 28, 1991.

The reservoir geology map presents no mapping of the conditions in the project area, but indicates that numerous explorations have been completed along portions of the planned fish passage alignment.

The Design Geotechnical Report dated February 1991 includes a geologic map (Figure 3) showing the north portion of the project area. The geologic map indicates bedrock in the river gorge below the dam, and non-differentiated deposits of colluvium, glacial till, and glacial outwash along the project alignment. The map also indicates glacial lacustrine clay deposits located along both sides of the river that appears to be interlayered in the non-differentiated deposits. The report includes only one boring (DH-101) that is located along the project alignment (approximately at screen location). The boring log indicates about 3.5 feet of fill overlying basalt bedrock. The fill consists of sand and gravel with silt.

SITE RECONNAISSANCE

General

A geotechnical engineer/engineering geologist from GeoEngineers, Inc. visited the site on December 13, 2002 to observe general site and near surface soil conditions. The reconnaissance included shallow hand holes to evaluated surface soils along the planned alignment. Our observations are described in the following paragraphs starting at the planned Eicher screen location and proceeding downstream along the bypass pipeline/flume alignment. The soil descriptions presented below are generally consistent with the descriptions presented on the geologic map included in the Converse Consultants NW 1991 report.

Eicher Screen

The Converse Consultants NW 1991 report included one boring at the approximate Eicher screen location. The subsurface conditions included about 3.5 feet of fill overlying basalt bedrock. The fill thickness likely increases toward the dam, because the penstock pipeline is exposed at a lower elevation than the existing parking lot. However, the Penstock Profile we reviewed shows bedrock through the screen area and adjacent roadway embankment at depths less than about 5 feet.

Bridge Crossing

The proposed bypass pipeline will be supported on the United States Forest Service (USFS) bridge. We expect that the pipeline will be supported on the bridge at about the elevation of the bottom of the deck support girders. The proposed bypass pipeline extends along the toe of the roadway fill embankment, from the Eicher screen location to the bridge support columns on the west side of the bridge. The depth to bedrock is not known in the area of the roadway embankment fill. However basalt bedrock is exposed about 20 feet below the bottom of the bridge in the river gorge. The roadway embankment fill in this area includes brown, moist medium dense, silty sand with gravel and occasional cobbles.

The surface soil conditions on the east side of the bridge include reddish-brown, moist, medium dense, silty sand with gravel and cobbles. These soil deposits are exposed in the slope below the east bridge abutment. Basalt bedrock is exposed in the river gorge about 20 feet below the east end of the bridge.

Distribution Vault

The bypass pipeline alignment crosses the east dam abutment access road and follows the Wynoochee Lake Shore Trail. The distribution vault will be located on the east side of the access road at the beginning of the trail. The ground surface in the planned distribution vault area is generally level but slopes up to the east along the east side of the trial. A drainage swale is located along the south side of the vault loctation. We observed brown, moist, medium dense silty sand with gravel in the area of the planned vault.

Wynoochee Lake Shore Trail

The lake shore trail appears to have been cut into the relatively gentle west facing slope that rises to the east of the east dam abutment access road. Cut slopes on both sides of the trail are inclined upward at about 1½H:1V (horizontal to vertical) or flatter. No apparent indications of slope instability were observed. The toe of the cut slope is located at about the edge of the east side of the trail along the first approximately 180 feet of the trail. The cut slopes flatten after the first approximately 180 feet on both sides of the trail, providing more room for the planned bypass pipeline/flume. We observed brown, moist, medium dense silty sand with gravel along the trail and at the toe of the dam fill embankment.

Powerhouse Access Road

We understand that the bypass pipeline/flume to be located down-slope of USFS Road 2312 will likely be an open box flume. The powerhouse access road heads down-slope to the south from USFS Road 2312. The flume will be located on the up-slope (east) edge of the road. The road also provides access to a substation that is located at the bottom of the slope where the road makes a hard right turn to the north to the powerhouse. The road is cut into the west facing slope and some fill appears to have been placed along portions of the west edge of the roadway. The cut slope is inclined upward to the east at about 1½H:1V to 1¾ H:1V. No apparent indications of slope instability were observed. We observed brown, moist, medium dense silty sand with gravel in the cut slope from USFS Road 2312 to the substation.

Substation to Outlet Channel

The proposed flume alignment extends from the access road across relatively level ground along the west side of the substation, through a small detention pond that remains from previous construction activities, to the area planned for the outlet channel. This portion of the alignment crosses what appears to be an alluvial bench located 20 to 30 feet above the current river elevation. The ground surface slopes down very gently to the south and west from the powerhouse access road to the small detention pond and outlet channel area. We observed brown, moist, medium dense silty sand with gravel along this portion of the alignment.

Outlet Channel

The outlet channel section begins about 50 feet south of the existing detention pond. An existing small forest road extends from near the southeast corner of the existing detention pond to the river gauging station (cable car crossing). Soil in the area of the outlet channel include dark brown, wet, loose silty fine sand and soft sandy silt along the road. These soils are also exposed in the river bank at the cable car crossing and farther south. A small creek flows from the east and into the river just south of the cable car crossing. It appears that the creek comes from a small ravine east of the site and is likely the source of the fine-grained soil in the outlet channel area.

A low narrow bench exists along the edge of the river. The bench generally extends about two to three feet above the river elevation and is about ten to fifteen feet wide where the channel will enter the river. The river deposits evident in the bench include sand, gravel, cobbles and boulders.

CONCLUSIONS AND RECOMMENDATIONS

GENERAL

Based on our review of existing information and the results of the field reconnaissance, it appears that the soils in much of the alignment will provide good support for the structures and pipeline/flume. However, we completed only widely spaced shallow hand dug holes to observe surface soil conditions and have not reviewed exploration logs from previous studies besides the one log mentioned above. No additional studies were available during the course of our review.

We recommend that additional explorations (test pits) be completed in the outlet channel area. This area is underlain by wet, loose/soft soil that may be problematic for channel construction. Furthermore, it may be desirable to complete explorations at the Eicher screen and distribution vault locations to reduce the risk of "changed condition" claims during construction.

The following paragraphs present our conclusions regarding subsurface conditions along the various portions of the project alignment and recommendations for additional review and explorations, as appropriate.

EICHER SCREEN

We expect that bedrock in the area of the Eicher screen will be 3 to 5 feet below the existing ground surface. Rock excavation may be a significant impact on the contractor's bid. We therefore recommend that additional explorations be completed once the screen location and elevations have been determined. As an alternate, it may possible to structure the bid documents to anticipate the potential extra cost of excavation with a line item for rock excavation.

BRIDGE CROSSING

Based on our observations, it appears that the bypass pipeline will be excavated in roadway embankment fill and native glacial deposits on both sides of the bridge. These soils should provide good support for a properly bedded pipe.

DISTRIBUTION VAULT

The distribution vault will be located on the east side of the access road at the beginning of the Wynoochee Lake Shore Trail. The native soil evident in this area should provide good support for the vault, provided loose roadway fill is not present below the vault. We therefore recommend that explorations be completed to determine the support conditions at the planned bottom elevation of the vault.

WYNOOCHEE LAKE SHORE TRAIL

The trail appears to have been cut into the slope along a portion of the alignment. The cut slopes appear stable. We expect that temporary cuts as steep as 1¼H:1V can be excavated along the toe of the adjacent slopes without creating instability. However, it appears that there is adequate space to locate the bypass pipeline/flume away from the slope located along the east side of the trail. If excavations in excess of about 4 feet are planned then it would be prudent to complete explorations to verify soil conditions at depth. The native soil evident in this area should provide good support for the pipeline/flume.

POWERHOUSE ACCESS ROAD

The east side of the access road appears to have been cut into the west facing slope and the slope appears stable. We expect that temporary cuts as steep as 1¼H:1V can be excavated along the toe of the adjacent slopes without creating instability. However, if excavations in excess of about 4 feet are planned then it would be prudent to complete explorations to verify soil conditions at depth. The native soil evident in this area should provide good support for the flume.

SUBSTATION TO OUTLET CHANNEL

The proposed flume alignment crosses what appears to be an alluvial bench located 20 to 30 feet above the current river elevation. The surface soils observed should provide good support for the flume. However, the firm silty sand with gravel changes to loose silty fine sand and soft silt near the beginning of the outlet channel. We recommend that explorations be completed to evaluate the extent of loose/soft soil and the depth to firm bearing. It may be necessary to remove and replace some of the loose/soft soil to provided proper support for the flume near the outlet channel.

OUTLET CHANNEL

The outlet channel begins about 50 feet south of the existing detention pond. The firm silty sand with gravel that is characteristic along much of the project alignment changes to wet, loose silty fine sand and soft silt near the beginning of the outlet channel. The loose/soft soil is also present in the river bank that will be excavated for the proposed channel. It is likely that permanent cut slopes must be inclined no steeper than 3H:1V to reduce the risk of instability. If significant amounts of groundwater seepage are present then flatter cut slopes or retaining structures may be necessary. We recommend that explorations be completed along the outlet channel alignment to evaluate the extent of loose/soft soil and the depth to firm bearing.

LIMITATIONS

We have prepared this report for the exclusive use of the U.S. Army Corps of Engineers-Seattle District, Tetra Tech, Inc. and their authorized agents for preliminary assessment of the proposed fish passage project at the Wynoochee Dam in Grays Harbor County, Washington.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in the field of geotechnical engineering in this area at the time this report was prepared. No warranty or other conditions, express or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table, and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers, Inc. and will serve as the official document of record.

Please refer to the attachment titled Report Limitations and Guidelines for Use for additional information pertaining to use of this report.

We appreciate the opportunity to provide geotechnical services on this project. Should you have any questions or comments, or if we may be of further service, please do not hesitate to call.

Respectfully submitted,

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Attachment

ATTACHMENT A

REPORT LIMITATIONS AND GUIDELINES FOR USE

ATTACHMENT A
REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

GEOTECHNICAL SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES, PERSONS AND PROJECTS

This report has been prepared for the exclusive use of the U.S. Army Corps of Engineers-Seattle District, Tetra Tech, Inc. and their authorized agents for preliminary assessment of the proposed fish passage project at the Wynoochee Dam in Grays Harbor County, Washington. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Because each geotechnical or geologic study is unique, each geotechnical engineering or geologic report is unique, prepared solely for the specific client and project site. Our report is prepared for the exclusive use of our Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Client and generally accepted geotechnical practices in this area at the time this report was prepared.. This report should not be applied for any purpose or project except the one originally contemplated.

A GEOTECHNICAL ENGINEERING OR GEOLOGIC REPORT IS BASED ON A UNIQUE SET OF PROJECT-SPECIFIC FACTORS

This report has been prepared for the proposed fish passage project at Wynoochee Dam in Grays Harbor County, Washington. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- the function of the proposed structure;
- elevation, configuration, location, orientation or weight of the proposed structure;

[1] Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org .

- composition of the design team; or
- project ownership.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

SUBSURFACE CONDITIONS CAN CHANGE

This geotechnical or geologic report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or ground water fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

MOST GEOTECHNICAL AND GEOLOGIC FINDINGS ARE PROFESSIONAL OPINIONS

Our interpretations of subsurface conditions are based on field observations from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

GEOTECHNICAL ENGINEERING REPORT RECOMMENDATIONS ARE NOT FINAL

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual subsurface conditions revealed during construction. GeoEngineers cannot assume responsibility or liability for this report's recommendations if we do not perform construction observation.

Sufficient monitoring, testing and consultation by GeoEngineers should be provided during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether or not earthwork activities are completed in accordance with our recommendations. Retaining GeoEngineers for construction observation for this project is the most effective method of managing the risks associated with unanticipated conditions.

A GEOTECHNICAL ENGINEERING OR GEOLOGIC REPORT COULD BE SUBJECT TO MISINTERPRETATION

Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also retain GeoEngineers to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering or geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

DO NOT REDRAW THE EXPLORATION LOGS

Geotechnical engineers and geologists prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering or geologic report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

GIVE CONTRACTORS A COMPLETE REPORT AND GUIDANCE

Some owners and design professionals believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering or geologic report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer. A pre-bid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might an owner be in a position to give contractors the best information available, while requiring them to at least share the financial responsibilities stemming from unanticipated conditions. Further, a contingency for unanticipated conditions should be included in your project budget and schedule.

CONTRACTORS ARE RESPONSIBLE FOR SITE SAFETY ON THEIR OWN CONSTRUCTION PROJECTS

Our geotechnical recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and to adjacent properties.

READ THESE PROVISIONS CLOSELY

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

GEOTECHNICAL, GEOLOGIC AND ENVIRONMENTAL REPORTS SHOULD NOT BE INTERCHANGED

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.

BIOLOGICAL POLLUTANTS

GeoEngineers' Scope of Work specifically excludes the investigation, detection, prevention, or assessment of the presence of Biological Pollutants in or around any structure. Accordingly, this report includes no interpretations, recommendations, findings, or conclusions for the purpose of detecting, preventing, assessing, or abating Biological Pollutants. The term "Biological Pollutants" includes, but is not limited to, molds, fungi, spores, bacteria, and viruses, and/or any of their byproducts.

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Appendix F

T.W. Sullivan Hydroelectric Plant

Site Visit Notes and Photographs

December 9th, 2002

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Appendix F. T.W. Sullivan Hydroelectric Plant Eicher Screen

Notes from Sullivan Plant Tour
Wynoochee Eicher Screen Feasibility Level Design

Date: December 9, 2002

Time: 9:30 AM to 1:00 PM

Location: Sullivan Hydropower Facility, Oregon City, OR – Willamette River

Owner: PGE

Attendees: Dan Domina (PGE), Chris Pollock (USACE-Seattle), Steve Fischer (Tacoma Power), Marc Wicke (Tacoma Power), Satendra Jain (Tt), Jake Venard (Tt), Bill Fullerton (Tt)

Purpose: Observe the Eicher screen facility installed in the PGE Sullivan plant, discuss its operation with PGE staff and transfer information such as engineering drawings

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The various tour participants met in the West Linn police station parking lot above the Pacific General Electric (PGE) Sullivan plant between 9:30 and 10:00 AM and accessed the power plant by walking upstream on a path along the left bank of the river. The plant facilities are located along the left side of the channel. There is a ship canal (Photo 1) and series of USACE-Portland locks (Photo 2) at the far left side of the channel. The power plant diversion channel is between the ship channel / locks and the actual powerhouse.

The first changes in the falls area dates back to the Oregon Trail period when the falls were partially dammed up to deepen the water upstream to facilitate steamships going up the Willamette River. The first hydropower was installed in the late 1880s. Original fish passage was constructed by carving a series of steps in the falls. Prior to changes to develop the falls area, there was natural fish passage.

The Oregon Department of Fish and Wildlife, installed an upstream fish passage facility at the falls in the early 1970s. It has ladders originating in four different locations. There is a facility at the ladder to count fish using the ladder. The ladder is a pool/weir and orifice type.

Around the falls is a concrete cap that raises the water to a uniform elevation of 52 feet (Photos 3-5). Flash boards installed along the top of the cap increase the elevation to 54 feet, which allows the plant to run at full capacity all summer. The concrete cap is anywhere from a foot or two above bedrock to nearly 20 feet. Dan indicated that they may install an Obermeyer weir, at an elevation below the crest, in the concrete cap / bedrock to provide additional downstream fish passage. Experiments with removing flashboards in selected areas indicated the fish are attracted to water spilling along the cap.

At the upper end of the diversion to the power intake, there is a screen with vertical bars at about 6" spacing. The screen is oriented perpendicular to the flow (Photo 7). At the time of the 1996 flood, the water level was several feet above the platform we were standing on at this location or about 15 feet above the river level.

The outlet from the fish bypass consists of a sloping metal chute and a fall of approximately 14 feet to the river, depending on flows and tidal influence, which extends to the base of the falls (Photos 7 and 8). The total flow diverted from the turbines to the fish bypass facilities is 50 cfs. Of the 50 cfs, 36 cfs is passed down the chute with fish and the other 14 cfs is dropped to the river vertically. The building above the chute houses the fish evaluation facility, which is set up to allow counting, capture, inspection and release of screened fish.

The screens above the actual penstock intakes run nearly parallel to the intake channel (Photo 9 Looking downstream along screens and channel, Photo 10 Looking upstream along the screens and channels). Rack spacing is 1 inch at units 1-3, 1.5 inches at units 4-12, and 6 inches at unit 13. It was indicated that the first, more drastically angled portion of the screens, which have a finer bar spacing of about 1" "starve" the first three or so penstocks, resulting in an reverse flow from downstream portions of the screens supplying flow to this upstream area. This results in a large eddy forming in the upper corner behind the screens. PGE is currently performing physical hydraulic models on the intake facilities to improve flow conditions. The intent of the screens is to guide the fish to the downstream most area, where the bar spacing is 6 inches and the flow leads to the unit 13. This unit has the Eicher screen installed, the other units do not have fish screening and bypass, thus fish entering the first 12 units pass through the turbines.

The powerhouse has 13 units, each passing 470 cfs and capable of generating a total of 16 Megawatts. There are 12 Kaplan and one Francis turbine. The Kaplan turbines run induction generators (Photo 11), while the Francis runs an exciter generator (Photo 12) that is used to bring the others on-line.

The Eicher screen is somewhat unique in that it does not occupy the full diameter of the penstock, instead, it extends from the invert of the penstock, at an angle of 19.3 degrees, to within approximately 3 feet of the top of the penstock. At this point, a second screen drops at an angle of 8.5 degrees across the vertical draft tube leading to the turbine. The second screen is fixed, while the first screen rotates into a reverse angle of 14 degrees for back flushing or neutral position. Steve Fischer requested that he would like a means to lower a camera into the Eicher screen area to allow inspection. He mentioned the idea of a pipe with a double valve system to get the camera into the pipe. The camera could be lowered into the flow using a telescoping rod or screw system. Dan Domina indicated that when bypass flows are reduced to less than 50 cfs, fish injury rates increase. He believes this is due to impingement.

Back flushing of the screens is initiated based on head loss across the screens as measured by pressure gages just U/S and D/S of the penstocks (Photo 13). When the head loss across the screen exceeds 1 foot, an indicator is lit in the control room. The flushing actually needs to be performed by manual actuation. The screens should be flushed before the head loss exceeds 1.5 feet, at which an alarm sounds. The maximum design force for the screens is based on 2 feet of head loss, so it is imperative that they be backflushed prior to this value being reached.

To complete a back flush cycle requires 17 minutes. It takes several minutes to change the screen orientation at both ends of the cycle and about 10 minutes of actual back flushing. When the screen is initially moved, there is a surge of debris that goes through the system. To avoid problems with the debris in the wicket gates, the load is reduced to zero at the turbine. After the gate reaches its back flush position, the full 470 cfs is allowed to flow through the system. Leaves are often the primary debris problem and are obviously worse in the fall. During high flow years, debris scoured from the channel bottom is also a problem. Steve Fischer stated that leaves will likely not be as big of a problem at Wynoochee because it is a reservoir, the screen operates in spring and summer, when leave supply is not large, and the forests above the project are primarily coniferous.

The screens are inspected and maintained annually during a routine plant shutdown period. The maintenance may require some removal of materials adhering to the screens, straightening of bars and removal of some material wedged between bars.

It should be noted that the proper functioning of this screen is essential to running the power plant. In most circumstances, if the screen goes down, except for the periodic back flushing, the rest of the plant has to cease operation.

A chain or cable at one time was used to lift the screen. It was replaced with a screw (Photo 14) which is operated hydraulically.

The bypass is in a rectangular conduit (Photo 15) that takes off the top of the draft tube and delivers the water to a reservoir (Photo 16) above and beyond the draft tube. The flow in the bypass tube can be shutoff by a knife gate (Photo 17). The bypass system up to the rectangular conduit can be drained by a second rectangular conduit (Photo 18), which is also controlled by a knife gate. This drain avoids stranding of fish in the portion of the draft tube above the screens. Water from the bypass conduit wells up into the Bascule gate reservoir (Photo 19). The reservoir plays a role in controlling the flow to the bypass. The method for controlling the flow through the bypass is fairly unique, and is functional due to the relatively small variation in the operating head. The flow is controlled by a Bascule gate that raises or lowers (Photo 18) based on the outflow of the second bypass system reservoir (or plunge pool). The outflow is based water surface elevation of the flow out of the second reservoir / plunge pool chamber. The plunge pool is used to dissipate the energy of the flow free falling several feet over the lip of the Bascule gate. The plunge pool can also be drained to avoid stranding of fish and for maintenance by a pipe leading out of the bottom of the plunge pool (Photo 20). This drain is also controlled by a knife gate valve (Note in the photo that the drain has some "dead space" between the valve and the plunge pool reservoir wall.).

A very functional system is used to facilitate counting, inspection and capture of fish. This system is housed, along with the plunge pool reservoir in an enclosure cantilevered over the Willamette River (Photo 21). While testing fish survival fish, 14 cfs is diverted to a flume reservoir (Photo 22) and then over a series of screens in the flume floor (Photo 23), and eventually to the fish holding tank (Photo 24). The remaining 36 cfs of the total 50 cfs bypass flows down the main discharge ramp (Photo 25). A screen can be placed over the outlet to prevent fish from exiting the holding tank. The flume can be raised or lowered by a chain to control the amount of flow going into the fish sampling/collection chamber (Photo 26).

Photos

Photo 1. Corps of Engineers ship canal at Willamette Falls, Oregon.

Photo 2. USACE-Portland locks at Willamette Falls.

Photo 3. The concrete cap at Willamette Falls.

Photo 4. The concrete cap at Willamette Falls.

Photo 5. The concrete cap at Willamette Falls.

Photo 6. Trash racks at upstream end of the Sullivan diversion intakes.

Photo 7. Outlet of fish bypass system.

Photo 8. Outlet of Fish Bypass System.

Photo 9. Looking downstream along the intake channel to the powerhouse and the louver screen.

Photo 10. Looking upstream along the powerhouse intake channel and fish screens.

Photo 11. Kaplin power generator.

Photo 12. Unit 9 Francis generator.

Photo 13. Eicher screen pressure gauge.

Photo 14. Screw that moves the Eicher screen.

Photo 15. Rectangular bypass pipe.

Photo 16. Reservoir that fish enter after the Eicher screen.

Photo 17. Knife gate on bypass pipe.

Photo 18. Drain pipe for screen system.

Photo 19. Bascule gate hydraulic arm.

Photo 20. Drain pipe for plunge pool.

Photo 21. Fish sampling station.

Photo 22. Vertical screen.

Photo 23. Screens on flume.

Photo 24. Fish holding pool.

Photo 25. Flow plunging downstream of vertical screen.

Photo 26. Flow control to fish holding chamber.

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Appendix G

Hatchery and Wild Fish Management

Background Discussion

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Appendix G. Hatchery and Wild Fish Management Background Discussion

The following section is provided for informational purposes only. This background information is included in order to stimulate discussion regarding the effects of hatchery supplementation on wild adult fish in the Wynoochee River.

Currently, the Wynoochee River adult fish trap is used to capture upstream migrating salmon and steelhead for either transport upstream of Wynoochee Dam or to a hatchery. Captured wild salmon and steelhead are transported and released into the river, upstream of Wynoochee Lake. Approximately 300 adult hatchery steelhead are transported to the Aberdeen hatchery as brood stock for the hatchery supplementation. In addition, a number of wild steelhead are also used to bolster the genetics of the hatchery stock used to supplement the Wynoochee River hatchery stock each year. Historically, wild fish have also been used to augment the numbers of brood stock used at the hatchery when hatchery fish returns do not meet the demand for the hatchery. Adult hatchery steelhead have also been transported and released into the Upper Wynoochee basin, which may potentially spawn with wild stocks.

Effects of hatchery supplementation on wild salmonid stocks is currently under scrutiny (Beckman et al. 1999). Studies have indicated that hatchery and hatchery x wild hybrids is lower than that for wild steelhead populations (Reisenbichler and McIntyre 1977; Chilcote et al. 1986; Leider et al. 1990; Camton et al. 1991; Byrne et al. 1992). Chilcote et al. (1986) stated that hatchery steelhead had lower reproductive success than native steelhead. Modeling by Byrne et al. (1992) indicated that supplementation of wild stocks with hatchery fish actually may result in a decrease in the wild population over time. Since the objective for installing the Eicher screen at the Wynoochee Dam is to improve wild fish survival, the potential effects of a hatchery supplementation program to mitigate for the five percent expected mortality at the dam after installation of the Eicher screen must be examined. It is possible that a long-term hatchery supplementation program may actually cause greater impairment to the fishery than the five percent mortality at the dam.

Installation of an Eicher screen at the Wynoochee Dam is expected to increase smolt survival through the dam from 70 to 95 percent, and produce a corresponding increase in adult returns. From 1992 to 2000 annual Upper Wynoochee basin smolt production for both coho and steelhead ranged from approximately 9800 to 21700 smolts (average = 17,200) (Marc Wicke, Tacoma Power, personal communication). Estimates of the expected annual adult returns based on the average, minimum, and maximum smolt production values at varying smolt-to-adult return rates (SAR) are presented in Table G1. Although these data are limited, they do suggest that at low SARs (less than 5 percent), removing wild adult fish from the fishery for hatchery supplementation brood stock could negate the increase in adult wild fish returns produced by improved survival from the Eicher screen. It is likely that periods of low wild fish returns would coincide with low hatchery fish returns, which are the periods when wild fish are used as hatchery brood stock to compensate for insufficient hatchery adults to meet smolt production goals at the hatchery.

Data expressed in Table G1 are a representation of average conditions and do not account for factors such as ocean and climatic conditions that may affect marine and freshwater survival. High variation in returns for both coho and wild steelhead counts at Wynoochee Dam also suggest that annual adult returns are influenced by factors other than mortality at the Dam. From 1971 to 2002, returns of adult coho ranged from 130 to 5698 and wild steelhead ranged from 42 to 2259. Further data analysis and examination of existing information may provide insight into the potential effects of hatchery supplementation on the wild stocks in the Wynoochee system.

	Minimum			Average			Maximum		
SAR	A_c	A_p	A_d	A_c	A_p	A_d	A_c	A_p	A_d
1%	69	93	25	120	163	43	152	206	54
2%	137	186	49	241	327	86	304	412	109
3%	206	279	74	361	490	129	456	618	163
4%	274	372	98	482	654	172	608	825	217
5%	343	466	123	602	817	215	760	1031	271
6%	412	559	147	722	980	258	911	1237	326
7%	480	652	172	843	1144	301	1063	1443	380
8%	549	745	196	963	1307	344	1215	1649	434
9%	617	838	221	1084	1471	387	1367	1855	488
10%	686	931	245	1204	1634	430	1519	2062	543
11%	755	1024	270	1324	1797	473	1671	2268	597
12%	823	1117	294	1445	1961	516	1823	2474	651
13%	892	1210	319	1565	2124	559	1975	2680	705
14%	960	1303	343	1686	2288	602	2127	2886	760
15%	1029	1397	368	1806	2451	645	2279	3092	814

Table G1. Estimated Upper Wynoochee River basin wild adult steelhead and coho returns at varying smolt-to-adult return rates (SAR) and the current 70 percent smolt survival through Wynoochee Dam (A_c) and expected 95 percent survival after implementation of an Eicher screen (A_p). Numbers are based on the minimum (9800), average (17,200), and maximum (21,700) annual smolt production (Marc Wicke, Tacoma Power, personal communication). The expected annual increase in adult returns (A_d) was calculated as the difference between A_p and A_c.

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Appendix H

Eicher Screen Reference Articles

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Development of an Eicher Screen at the Elwha Dam Hydroelectric Project

Pieter Adam, P.E.[1]
Donald P. Jarrett, P.E.[2]
Allan C. Solonsky[3]
Larry Swenson, P.E.[4]

Abstract

The Eicher Screen is a relatively new concept for screening juvenile fish out of hydroelectric turbine penstocks. The concept was developed by Mr. George Eicher and one was recently installed and evaluated at the Elwha Hydroelectric Project in Washington State. The Eicher Screen was installed inside a 9-foot diameter penstock in March 1990. The screen assembly consists of wedgewire panels of varying porosities mounted on a support frame. A pivot shaft inside the penstock allows the screen to be rotated and backflushed for cleaning. Hydraulic analyses, operational testing and initial biological evaluation were conducted from April through June 1990. Maximum headloss measured through the screen never exceeded two feet (0.61 m) and debris has not created any problems at the site to date. Biological evaluations consisted of passing 5,000 coho salmon smolts through the screened penstock. Over 99 percent of the fish were recovered from the penstock and survived a three day holding period. Additional biological evaluations will be performed in 1991.

Introduction

The Elwha Hydroelectric Project is currently undergoing FERC licensing. The Project was constructed in 1911 without upstream or downstream fish passage facilities and restoration of anadromous fish runs above the Project is a central licensing issue. Restoration is a goal shared by the Project's owner, James River II, Inc. (JRII), federal and state resource agencies and the Lower Elwha Indian Tribe.

To provide effective protection for future downstream migrants (juvenile fish), several alternatives were reviewed representing a range of complexity, cost and potential for success. These included conventional

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systems acceptable to regulatory agencies, such as traveling belt or angled drum screens or shutdown and spill options. An alternative, the Eicher Screen, is a relatively new concept of screening that holds promise for good performance. An economic evaluation indicated that, assuming reasonable Eicher Screen bypass flow requirements, its life cycle costs would be lower than a forebay screening facility or the shut down and spill alternative. The Eicher Screen alternative was attractive to JRII as a cost effective method to provide passage survival rates necessary to achieve restoration of anadromous fish. James River is presently engaged with the Electric Power Research Institute (EPRI) in the evaluation of the effectiveness of the Eicher Screen technology.

The basic concept of the Eicher Screen is a smooth, elliptical screen positioned at a shallow angle inside a penstock. Bypass flows exit the penstock through a pipe at the downstream end of the screen. According to George Eicher, successful fish passage is provided as long as the ratio of Vx (velocity component in the plane of the screen, parallel to the screen centerline) to Vz (velocity component perpendicular to the plane of the screen) is maintained at three to one (Figure 1).

In 1980, a prototype installation was tested at the T.W. Sullivan Plant at Willamette Falls, Oregon. Although poor hydraulic conditions were present at the site, studies indicated that the screen had a diversion efficiency near 100 percent. An accurate assessment of injuries to fish was precluded by injuries caused in the fish collection facilities. The collection facilities are currently being rebuilt and further testing will occur in 1991. With promising passage results, EPRI funded model tests at the University of Washington in 1984. During these tests, various species of fish were passed through an inclined plane screen in a rectangular cross-sectional model. Screen angles of 10.5, 16.5 and 30 degrees were tested over a range of varying bypass and approach flows. Results from the model tests indicated that fish touched the screen more frequently when screen angle was increased. These initial test results provided a starting point for the Elwha design. U of W Testing

Fisheries Considerations

Federal and Washington State design criteria (Vx and Vz) for conventional screening technology are based upon the site specific size and swimming capabilities of the juvenile fish present. At Elwha Dam, primary anadromous species targeted for restoration are chinook salmon, coho salmon and steelhead trout. Chinook salmon migrate downstream as sub-yearlings at approximately four inches (10 cm) in length. Coho salmon and steelhead trout migrate downstream as yearlings reaching lengths of five to eight inches (13 to 21 cm), respectively.

Using conventional forebay screening facilities, fish at Elwha Dam would limit the maximum Vz velocity component to 0.8 fps (0.24 m/s). A Vx velocity component at least twice the Vz velocity component would also be required according to federal and Washington State screening criteria. Because the Eicher Screen does not adhere to conventional screening methodology, only general guidelines were available to engineers and biologists during development of the Eicher Screen technology. Resource agencies and the Tribe required that careful evaluation of the Eicher Screen be performed to demonstrate that it can achieve equal or better passage rates than conventional screens.

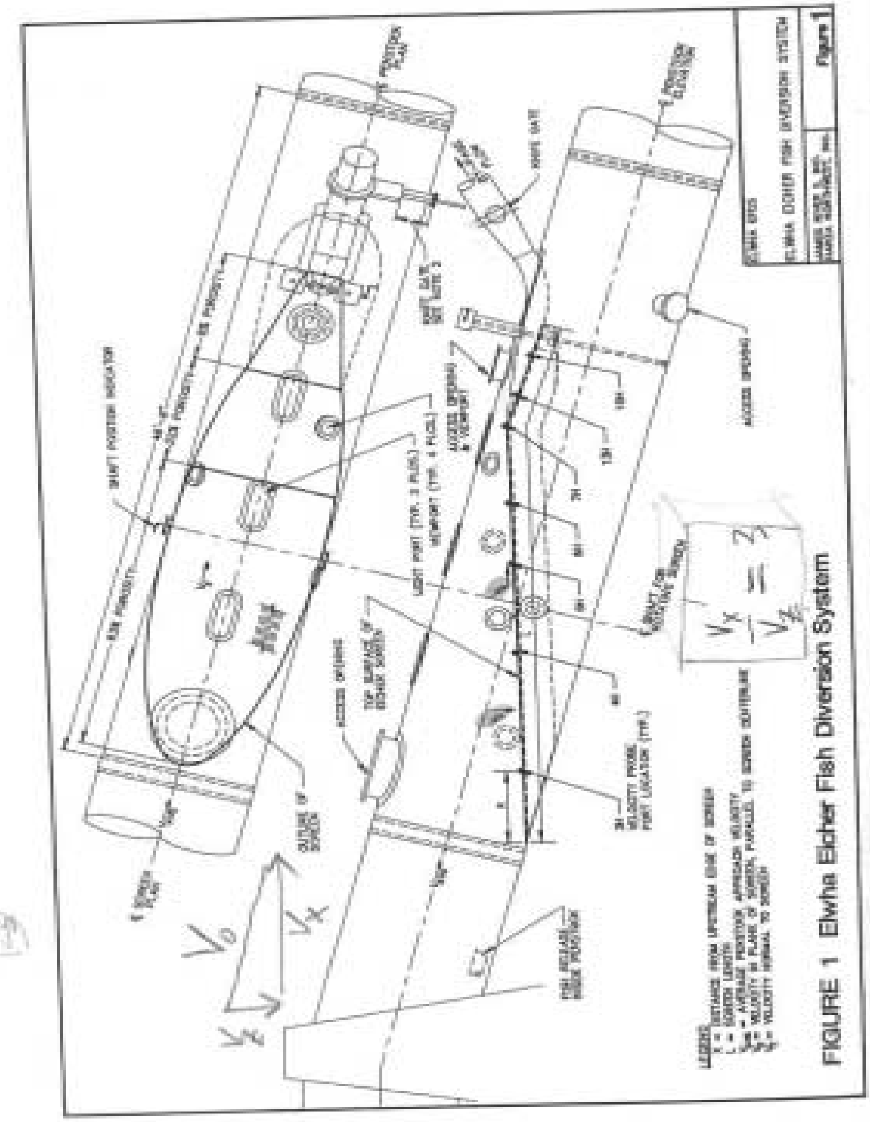

FIGURE 1 Elwha Eicher Fish Diversion System

Design Objectives

In the absence of established design criteria, development of screen parameters was a product of a consensus among the resource agencies, tribal representatives, JRII, JRII's consultant (Harza NW staff), George Eicher, EPRI, and EPRI's consultant (Stone & Webster). The process of design and evaluation was guided by a study plan which was jointly developed. The overall goal for the system was to provide 95 percent passage survival for all downstream migrating fingerlings and yearlings.

Because there was general belief that velocity components should have absolute limits, specific hydraulic objectives to provide effective fish protection were to develop a uniform Vx component (not to exceed about 10 fps (3 m/s) at full-gate) and limit the Vz component as much as practical. Additional design objectives were to minimize economic costs, such as initial capital cost and lost power generation due to fish bypass flows, minimize operational constraints, minimize headloss and provide effective debris management.

The Elwha Eicher Screen required several sub-assemblies and fabrications (Figure 1). Provisions were made for pivoting the screen, viewing ports, lighting ports, velocity measurement ports and mandoors for access into the penstock.

Hydraulic Model

A model study was conducted by Engineering Hydraulics, Inc. to help achieve the desired velocity patterns near the screen and minimize headloss. A 1:4.7 scale hydraulic model of the intake, penstock, screen and bypass was constructed. The penstock was modeled using 24-inch clear acrylic tubing. Maintaining the same screen headloss coefficients in the model and the full-scale penstock screen required using penstock screen material in the model and operating at penstock velocities, thereby producing full-scale Reynolds Numbers in the model. Since the scale of the screen material was 1:1 and the support beams were scaled 1:4.7, the model did not have strict geometric similarity. The screen bars and openings of the model were large relative to the size of the support beams and to the model penstock diameter. Nevertheless, it was believed that the overall flow patterns in the model would be similar to the full-scale screen because of the high model Reynolds Number (in the range of 0.7×10^6 to 1.4×10^6).

Three flow combinations were tested in the model: 4 fps (1.2 m/s) average velocity in the penstock and bypass pipe, 6 fps (1.8 m/s) in each and 8 fps (2.4 m/s) in each (referred to as 4-4, 6-6 and 8-8 respectively). Velocity measurements were made using a United Sensor five-hole prism probe. The probe was inserted through ports in the wall of the penstock at various locations (Figure 1). The probe axes were parallel to and about 3/8-inch (0.01 m) above the screen surface. The piezometric head measured at each of the five prism sensor ports was resolved to determine the three orthogonal velocity components for each velocity reading. Velocities are presented in a normalized format, where the actual velocity component (either Vx or Vz) is divided by the average penstock velocity. Normalized velocities allowed easy comparison of the velocity profiles under different flow conditions (Figure 2).

An initial model test using 63% porosity screen was performed. This test indicated a peak normalized Vx component in excess of 1.5 and a peak

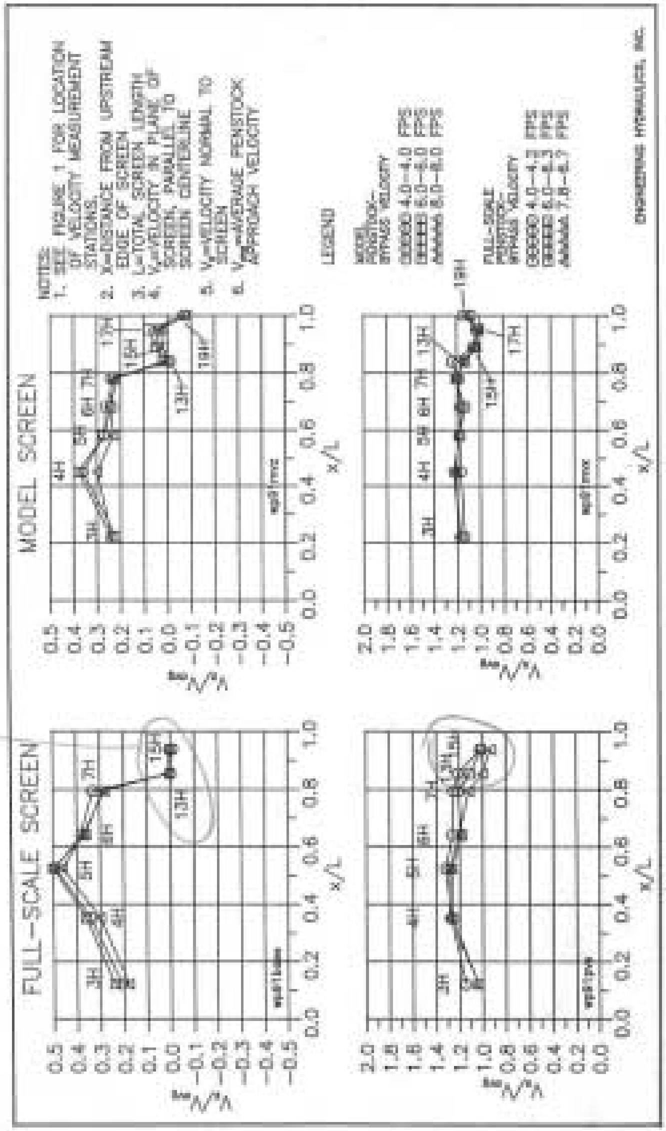

Figure 2 Full-Scale and Model Screen Velocity Data — Traverse Averages

normalized Vz component of 0.4. Subsequently, a series of tests were performed with various combinations of baffles to simulate different screen surface materials. The objective of these tests was to develop a screen design with a uniform normalized Vx component along the length of the screen and to limit the normalized Vz component to as uniformly low a value as practical. The variation of the normalized Vx and Vz components along the length of the screen are illustrated in Figure 2. A final model test was performed with actual wedgewire porosity to confirm the results with baffles.

In order to handle the hydraulic load caused by accumulated debris under emergency conditions, the design criterion for the screen (and frame) was set at 7 psi (48 kPa). This criterion required relatively deep backing bars for support. During model testing it was determined that the deep backing bars created excessive head loss (greater than 3 feet (.9 m)) and consequently, the backing bars were rotated to be more in line with the direction of the flow. It was also determined that spacing between the support bars should be kept as large as practical (8.25-inches (0.2 m) for the Hendrick material selected) in order to minimize head loss. Screen induced head losses were determined by measuring the difference in average piezometric head upstream and downstream of the screen. Figure 3 illustrates the head loss measured in the model study for the initial and final screen support bar arrangement.

Screen Configuration

A major design issue was the selection of the screen surface material. All parties believed that a screen built from stainless steel profile bars (referred to as wedgewire screen) was the best material to minimize debris accumulation and injury to fish. Several types of wedgewire screen were reviewed. Ultimately, material from Hendrick Screen Co. was selected.

Screen porosity was an additional design issue. Screen porosity affects head loss, debris management, velocity distribution and fish injury. Relatively large openings between screen bars could increase injury to fish and increase debris retention. A 63% porosity was considered to be a reasonable compromise between the need to minimize head loss, provide fish protection and maintain the ability to pass debris. The 63% porosity was achieved by using the manufacturer's standard bar width and the maximum allowed Washington State Department of Fisheries' opening between bars of 0.125-inch (0.3 cm).

Most participants agreed that some type of variation in porosity would be required in order to maintain uniform velocities along the length of the screen. This variation in porosity would eliminate the tendency for most of the flow to go through the downstream end of the screen, as has been observed in angled and inclined bypass facilities. Based on model studies, the final porosity configuration selected for the Elwha penstock screen was 63% for the upstream 2/3 of the screen and 32% and 6% for the remainder. This combination of porosity, based on the model results, was found to yield a relatively uniform Vx component along the length of the screen with reasonable limits to both Vx and Vz components.

Fish Bypass

Design of the bypass entrance area (transition from penstock to bypass) was considered critical for successful fish passage. Most participants felt that velocities through the transition section should not exceed about 10 fps in order for fish to maintain orientation into the flow.

Original concepts had a small pipe (2-foot (0.6 m) or less) intersecting at a shallow angle to the penstock section. The pipe would intersect a small area on the top of the penstock. This would require fish to travel to the extreme downstream end of the screen to be swept into the elliptical shaped bypass entrance. This geometry concerned fisheries biologists who felt that fish following the peripheral areas of the penstock could sustain high injury rates at the abrupt transition into the bypass. There also was a concern about a potential drop in velocity at the bypass entrance. Subsequently, George Eicher suggested a modified bypass entrance geometry which would solve these problems and the new geometry was selected for the screen (Figure 1). The modification provides a more gentle transition from penstock to bypass.

Bypass Velocity

The dimension of the bypass entrance was also an economic issue because it established the required bypass flow. The bigger the entrance the larger the bypass flow and the greater the economic cost of operating the Eicher Screen. A small entrance opening would run the risk of becoming clogged with debris. Ultimately the parties agreed to a final entrance height of 16-inches (0.4 m).

The bypass design includes a truncation of the screen at the downstream end, a transition to a rectangular shape and a second transition from a rectangular shape into the 24-inch (0.6 m) diameter bypass pipe. The bypass portion of the penstock section was consequently complex and considerable reinforcement was required to maintain the penstock's structural integrity. The model study indicated a more favorable Vx distribution along the length of the screen if 8% porosity wedgewire screen was used in the floor of the transition section. According to the model, porosity higher than 8% created excessively high velocities in the fish bypass entrance (1.5-1.6 normalized Vx).

Screen Support Frame & Pivot System

The wedgewire screen was mounted on a structural frame for support. The frame was required to be strong enough to support a fully clogged condition. Based on the model studies performed at the University of Washington, an angle of 16.5 degrees was selected as a reasonable compromise between effective debris management, fish passage and cost of construction.

The support frame was designed to pivot in order to enable backflushing the screen for cleaning. Two options were evaluated during the design phase to pivot the screen: hydraulic cylinders and a lead screw arrangement. Operator loads were expected to become quite large if debris loading was non-uniform. Because of the size of the support frame, it was decided to use two operators, one at each corner of the downstream end of the frame. Hydraulic cylinders were not used because the long rods would be subject to buckling. Furthermore, the frame could be subjected to distortion if debris prevented one side of the screen from returning to the "fishing" position. Twin lead screws were selected as being relatively inexpensive and not subject to imposing a torsional load on the frame, since the lead screws would be driven by a single gearbox.

Installation

Site specific installation issues that were unusual at this site included an old penstock with an irregular diameter and limited access. The condition of the penstock material was assessed by a metallurgical analysis. The

penstock shell material was found to be readily weldable, but only .19-inch (0.5 cm) thick. The interior of the penstock was physically inspected and found to be in reasonably good condition for its age. Due to the difficulty of field fabricating the bypass transition section and numerous penetrations, it was decided to fabricate a new penstock section and install the screen assembly into place on site.

Due to schedule constraints, the replacement penstock section and the screen were not assembled in the fabrication shop together. This resulted in field modifications which were required to align the 8% screen surface to the bypass transition section within allowed tolerances (0.125-inch). Because the existing penstock was out-of-round and could not be brought into a round condition, a short transition section was field fabricated and installed between the penstock and the replacement penstock section.

Biological Evaluation Results

An injury classification system developed by the National Marine Fisheries Service for studies on the Columbia River was used to evaluate fish passage success through the Eicher Screen. Categories of injuries were:

- "partially descaled" (scattered or patchy scale loss 3 to 16% per side);
- "descaled" (over 16% scale loss on one side); and
- "other injuries" (bruises, cuts, eye injuries, etc.).

All fish were held from three to ten days following tests. Results from over 5,000 fish passed through the screened penstock in groups of 100 fish indicated that the recovery rate averaged over 99 percent. Little or no injury was observed during tests conducted at low penstock velocities and at highest penstock velocity (full gate) only 3.6 percent of the test fish showed substantial injury (descaled). At full gate, an average of approximately 24% of the fish also exhibited partial descaling. Actual mortality (fish killed) during spring tests was 0.21 percent; all these fish died during fresh water holding. Studies to determine the effectiveness of diverting larger and smaller fish (steelhead yearlings and chinook sub-yearlings) will be conducted in 1991.

Hydraulic Evaluation

Velocity measurements at the Elwha screen were made in locations close to those in the model, but were shifted slightly due to interference with penstock stiffener rings. Measurements indicated reasonably good agreement with the model for the normalized Vx velocity component, but a higher peak normalized Vz velocity component (Figure 2). Observations made during the biological tests indicated that there were short term fish contacts with the screen in the area where the peak Vz velocity was measured (only at 6-6 condition).

The higher peak Vz components measured at the Elwha screen may be due to the fact that the model was not fitted for the screen seal and clamping bars. These two items increase the Vz component by blocking about 15% of the surface of the main screen. The higher velocities may also be due to different locations used for velocity measurements. The measurement location for 5H, for example, was situated over higher porosity screen and an area of unexpected high velocities.

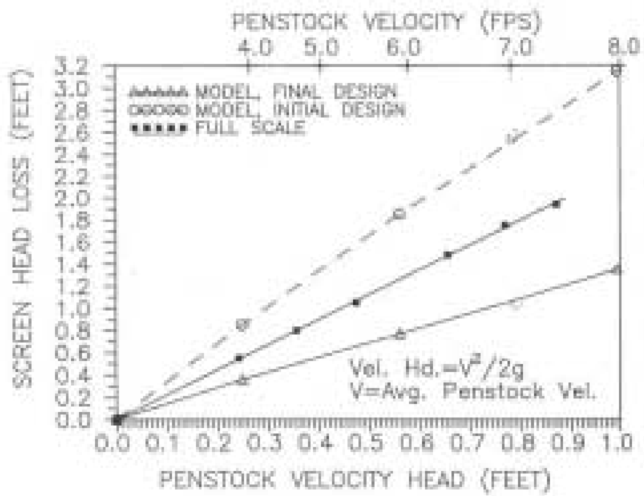

Figure 3 Full-Scale and Model Screen Head Loss

Head loss measurements at the Elwha Screen were made in the same manner as the model study. The head losses measured in the field indicated a maximum of 1.9-feet (0.6 m) and the maximum measured in the model was 1.3-feet (0.4 m), see Figure 3. The difference in head loss between the full scale and model measurements could be due to the lack of seals and clamping bars in the model. Additionally, some of the wedge wire support u-clips were removed during the model runs, which probably resulted in lower head loss.

Operational Impacts and Costs

No operational impacts have been noted to date. The screen cleaning system has been successful in removing any accumulated debris. Screen head loss at the site represents a negligible reduction in generation.

The construction cost for the installation of the Eicher Screen was about $400,000 (1989 dollars). This construction cost included about $80,000 for the installation of a crane to service this installation as well as other nearby construction. Additionally, there was another $400,000 incurred for professional services, the hydraulic model and lost generation (during installation and evaluation). A cost estimate to install Eicher Screens in all four penstocks at the Elwha Project, including bypass facilities is $3 million. A series of forebay drum screens is estimated to cost approximately $7 million.

Recommendations for Refinement

Based on the results of the biological evaluation and the prototype hydraulic tests performed to date, minor refinements may be made to improve performance. If refinements are made, it will be important to make hydraulic measurements following any modifications to the existing design. These measurements will provide a better understanding of observations made during biological tests.

Conclusion

Initial results from the Elwha Dam Eicher Screen are very encouraging. It is expected that with some minor modifications, fish contacts with the screen can be reduced. Future testing will determine the effectiveness of the screen to handle debris loading and the ability of the screen to successfully pass other species of fish. Gaining information at new sites with different fish species will also provide valuable information with which to understand required velocity conditions for the Eicher Screen technology. If tests continue to be successful, it is expected that the Eicher Screen will be a viable solution to downstream passage at other sites.

Acknowledgements

The authors are grateful to Orville Campbell of James River II, Inc. and Charles Sullivan of EPRI for their support in publishing this paper.

Evaluation of an Eicher Fish Diversion Screen at Elwha Dam

Fred C. Winchell[1] and Charles W. Sullivan[2]

Abstract

In the spring of 1990, the Electric Power Research Institute (EPRI) initiated testing of an inclined fish screen installed in a 9-foot diameter penstock at the Elwha Hydroelectric Project in Washington State. In tests performed with coho salmon smolts, over 99 percent of the fish were diverted without mortality. At penstock velocities from 4 to 6 fps, less than 0.1 percent of the fish had scale loss exceeding 16 percent on either side (considered "descaled" in criteria used on the Columbia River), and less than 5 percent showed any type of injury. Slightly more descaling was observed at higher penstock velocities. At the maximum velocity tested (7.8 fps), 3.6 percent of the fish had scale loss of over 16 percent, and 18.1 percent of the fish had scale loss between 3 percent and 16 percent. Mortality after a 3 to 10-day holding period averaged 0.21 percent for test fish and 0.14 percent for controls.

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Introduction

The concept of installing a fish screen inside of a penstock at a shallow angle to the flow was first applied by George Eicher at the T.W. Sullivan hydro plant in Oregon. This type of screen is now commonly referred to as an "Eicher Screen." Its basic principle is to sweep fish rapidly towards a bypass at high velocities, as opposed to other types of screens which are designed to maintain velocities lower than the swimming speed of the target fish species.

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Advantages of Eicher's design include low capital and maintenance costs, minimal space requirements, minimal icing potential and insensitivity to forebay level fluctuations. However, a demonstration of the screen's ability to safely pass fish is necessary before it can gain widespread acceptance.

This paper describes the evolution of the Eicher Screen design from its initial installation at the Sullivan hydro plant to the refined prototype recently installed at the Elwha Hydroelectric Project in Washington state. The results of passage tests performed in 1990 with coho salmon smolts are presented. Passage tests for coho salmon and other species will be continued in 1991 and in following years.

Background

The original "Eicher Screen" was installed in 1980 at Portland General Electric's T.W. Sullivan hydro plant at Willamette Falls, and is still in operation. It consists of a 21-foot long stainless steel wedgewire screen with 0.08-inch (2 mm) bars and 0.08-inch openings between bars. The screen is located inside an 11-foot diameter penstock, and is inclined at a slope of 19 degrees to the flow, leading to a surface bypass. The average water velocity through the penstock is approximately 5 fps.

The screen at the Sullivan plant has been relatively free of operational problems. Despite non-uniform flow conditions caused by the layout of the intake and penstock, testing has shown that the screen can divert several species of smolts at high rates. However, an accurate evaluation of fish injury has been precluded by the lack of adequate fish collection facilities. New test facilities planned by Portland General Electric should provide more information on the effectiveness of this screen in the near future.

Without conclusive data on fish injury rates, the Eicher screen has been slow to gain agency acceptance. In order to test and demonstrate the concept's potential, the Electric Power Research Institute (EPRI) initiated a research and development effort in 1984. This program started with laboratory studies conducted at the University of Washington and has culminated in the current test program of the Elwha prototype.

The University of Washington laboratory studies were conducted in a plexiglass flume, with a screen mounted in a test section 8-feet in length and 6-inches in width. The effects of bypass and flume velocities, screen angle, lighting, and various screen materials on the passage of several species of salmonid juveniles and smolts were examined. Fish were effectively diverted under a wide range of velocity conditions. Impingement did not occur at conditions where a high sweeping velocity was maintained along the full length of the screen. At most conditions where impingement did occur, it was limited to the area approaching the bypass entrance. Impingement was reduced or eliminated when the spacing between bars was reduced from 2 mm to 1 mm in the 18-inches of screen closest to the bypass entrance.

Soon after beginning the laboratory tests, EPRI started a search for a suitable site to test a prototype installation. The Elwha Hydroelectric Project, located on the Elwha River near Port Angeles, Washington was selected. With four 3.2 MW units and a total project flow capacity of 2,000 cfs, the site offers a high degree of operational flexibility for testing. The exposed section of the Elwha penstocks provided good access to several possible installation sites. Unlike the Sullivan plant, good alignment of the intakes and penstocks indicated that relatively uniform flow fields could be expected.

In 1989, EPRI entered into an agreement with the project's owners, James River II Inc., to evaluate the Eicher screen in one of the 9-foot diameter penstocks at the Elwha plant. James River II Inc. funded design and installation of the Eicher screen, including a hydraulic model study which was used to refine the initial design. EPRI funded design and installation of evaluation facilities and is also funding the ongoing biological and hydraulic evaluation of the screen.

Prototype Design

James River II Inc. contracted with Hosey and Associates Engineering Company to design the prototype screen and oversee hydraulic model testing. Hosey, in turn, contracted with Engineering Hydraulics, Inc., to build the model and conduct the laboratory tests.

A model of the intake, penstock and screen was constructed on a scale of 1 to 4.7 to develop detailed information on the flow field immediately upstream of the Eicher Screen and in the fish bypass. The initial design used profile bar screen with uniform bar spacing. The screen angle was set at 16 degrees to the penstock for all tests, except for a short section of screen in the bypass transition which was roughly parallel with the penstock.

Two major refinements were made to the screen design during the hydraulic model studies. The design of the support structure was streamlined in order to reduce headloss, and the porosity (percent open area) of the screen was reduced in the downstream end of the screen to provide a more uniform flow field over its entire length.

The prototype using the refined design was installed in the spring of 1990 as part of a 46.5-ft long, prefabricated penstock section. Plan and section views of the screen are shown in Figure 1. The inclined portion of the screen is comprised of two sections with uniform bar width (0.073-inch or 1.9 mm) but different bar spacing. The upstream section is 20-feet in length, has a porosity of 63 percent with an opening between bars of 0.125-inches (3.2 mm). The downstream section is 7.5-feet in length and has a screen porosity of 32 percent with an opening between bars of 0.035-inches (0.9 mm). The section of screen in the bypass transition is 7 feet in length and has a porosity of 8 percent, with an 0.093-inch (2.4 mm) bar width and an 0.008-inch (0.2 mm) opening between bars. The entire screen including the transition section is designed to pivot so that it can be cleaned by backflushing or put into a position parallel to the penstock when not in use.

The Elwha Testing Program

EPRI initiated its testing program at Elwha in the spring of 1990 with

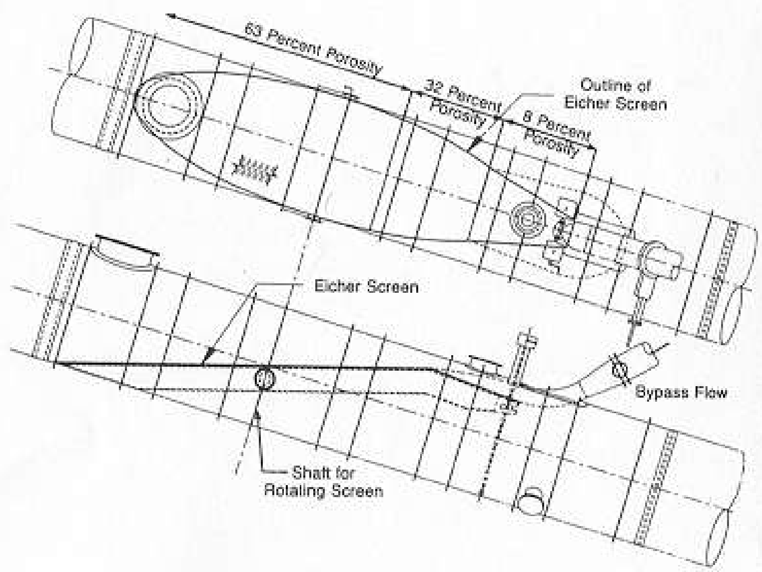

Figure 1. Plan and Section Views of the Elwha Eicher Screen (courtesy Harza Northwest and Hydro Review).

construction of evaluation facilities and completion of the first series of tests with coho salmon smolts. Stone & Webster Environmental Services was retained by EPRI to review hydraulic modelling efforts and design the evaluation facilities. The testing program was developed in a cooperative effort by Stone & Webster and Hosey & Associates with extensive input from state and federal fishery agencies and the Lower Elwha Tribe. A detailed report on the tests performed in the spring of 1990 is presented in EPRI Report No. GS-7036, "Evaluation of an Inclined Penstock Screen at Elwha Dam, Spring 1990 Test Results" (in press). Testing will be continued in 1991 with smolts of steelhead trout, chinook salmon and additional coho salmon.

Evaluation Facility Design

The evaluation facilities installed at Elwha are shown in Figure 2. A pressurized system is used to release test fish into the penstock upstream of the screen. this system is composed of a 60-gallon fish release tank connected to an 8-inch diameter release pipe. The fish are released into the penstock by gradually displacing the water from the release tank and pipe with compressed air. The system releases the fish into the base of the

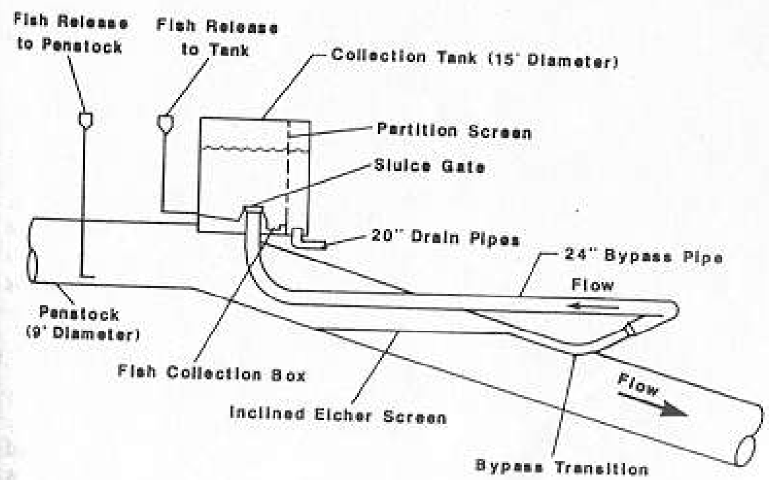

Figure 2. Section View of the Elwha Evaluation Facilities.

penstock approximately 15 feet upstream of the leading edge of the screen. An identical system releases the control fish into the collection tank.

Bypassed fish are delivered into the collection tank through a 24-inch pipe, which discharges the bypass flow and fish upward vertically through an open sluice gate at the floor of the tank. Bypass flows are regulated by adjusting the elevation of the water in the tank, with depths ranging from 7 to 10 ft for the range of bypass flows evaluated (4 to 7.8 fps). The water level in the tank is controlled by adjusting two 20-inch valves which drain flow from the tank behind a screen partition designed to retain collected fish in the tank.

When a test is completed, the tank is drained and the fish are guided by the sloped floor into a 60-gallon collection box. The box is lifted to the uppermost of three work decks surrounding the collection tank. Tanks are provided on the middle and upper decks to hold groups of fish prior to release and following recovery.

Test Parameters

Six combinations of penstock and bypass velocities were evaluated, as shown in Table 1. Penstock velocities were selected to cover the normal operating range of the turbine. Based on results of the University of Washington laboratory studies, the velocity at the bypass entrance was set equal to or greater than the average velocity in the penstock to minimize the potential for fish impingement. The condition with 7 fps in the penstock and bypass was added after a slight increase in injury rate was noted between the 6 fps and 7.8 fps (full gate) penstock conditions.

A study schedule was developed which replicated each test condition twelve times over a fifteen day period. Since the 7 fps condition was added later in the tests, it was only replicated five times. In order to examine time of day as a variable that could affect passage success, each of the five primary conditions were replicated six times during daylight hours and six times during hours of darkness.

Test Methods

The coho smolts used in the spring 1990 testing program were obtained from the Lower Elwha Tribal Hatchery. They were reared for five months to an average size of 135 mm in a net pen located in the forebay of the Elwha project. The fish were monitored to assure that they were in peak migratory (smolted) condition at the time of the tests. At this time, they are most prone to scale loss injury. The 15-day test program was initiated on May 19, 1990, and covered the period of peak smoltification.

Table 1. Test Conditions Evaluated in the Spring of 1990.

Penstock Velocity (fps)	Bypass Velocity[1] (fps)	Turbine Flow (cfs)	Bypass Flow (cfs)	Wicket Gate Position (%)	Test Replicates Day	Test Replicates Night
4	4	240	11.8	48	6	6
4	6	240	17.7	48	6	6
6	6	360	17.7	70	6	6
6	7.8	360	23.0	70	6	6
7[2]	7	425	20.6	88	2	3
7.8	7.8[3]	475	23.0	100	6	6

[1] Average velocity at the downstream terminus of the bypass transition.

[2] The 7/7 condition was added after a slight increase in injury was noted at the 7.8 fps penstock condition.

[3] 7.8 fps was the highest bypass velocity that could be maintained for extended periods due to wave action in the collection tank.

Before testing, fish were marked with one of four colors of dye pneumatically injected at one of seven locations, producing a total of 28 distinct marks. Marked groups of 100 fish each were held in square, 100-gallon fiberglass tanks situated on the middle deck of the evaluation facility. Each fish was later examined to assure that its mark was visible, to cull out any fish with significant scale loss or other injuries, and to obtain an accurate count of the fish remaining in each mark group.

At the initiation of testing each day, the Eicher Screen was moved from the neutral position (with the screen parallel to the penstock flow) to the fishing position (with the screen at a 16 degree angle to the penstock). Penstock and bypass flows were then set to the first scheduled test condition. A final count was then made as the fish were transferred into buckets. Next, the fish were poured into the appropriate release tanks and the covers were closed and sealed. The fish were then gradually purged from the release systems.

The bypass flow specified for the test condition was maintained for five to ten minutes after fish were released. When the bypass velocity was 7 fps or less, a run time of 10 minutes was used. At a 7.8 fps bypass velocity, the run time was reduced to 5 minutes. These durations were found to be sufficient to allow the fish to pass through the system into the collection tank.

After a test was completed, the inlet sluice gate was closed and the collection tank was gradually drained. Most of the fish moved readily into the collection box as the water depth dropped. The collection box was then hoisted to the upper deck of the evaluation facility.

Fish were evaluated immediately after recovery, directly from the collection box. Each fish was anesthetized and its dye mark, fork length and condition was recorded. A classification system developed by the National Marine Fisheries Service for studies on the Columbia River was used to categorize injuries. The major categories used were:

- o "partial descaling" (scattered or patchy loss 3 to 16% per side);
- o "descaled" (over 16% scale loss on one side); and
- o "other injuries" (bruises and eye injuries).

Fish recovered during the first half of the study were held for three days following recovery to assess delayed mortality. In the last half of the study, the loading density in each tank was increased to enable fish to be held for six to ten days.

Test Results

Results from over 5,000 fish passed through the Eicher Screen prototype indicate that the screen safely diverts coho salmon smolts under a wide range of operating conditions (Table 2). The recapture rate for test and control fish averaged over 98% for each of the test conditions evaluated. Recapture rates increased with time as release and recovery techniques were improved upon. During the last ten days of testing, only 5 fish out of the 3,365 fish released into the penstock were unaccounted for. Four of these fish were lost at test conditions with a penstock velocity of 4 fps, which appears to be too low a velocity to prevent some coho smolts from escaping upstream.

Little or no injury was observed during tests conducted at penstock velocities of 4 or 6 fps. Slightly more injury occurred at higher velocities, but even at the highest velocity condition tested (7.8 fps) only 3.6 percent of the test fish had over 16% scale loss on either side.

Table 2. Summary of Evaluation Results with Coho Salmon.

Penstock/Bypass Velocities (fps)	Replicates		Fish Recovered	Injury Class >16% Descaled	3-16% Descaled	Other Injuries	Delayed Mortality
4/4	Test	12	99.6%	0.0%	0.8%	1.0%	0.3%
	Control	12	100.0%	0.0%	1.2%	0.7%	0.0%
4/6	Test	12	99.2%	0.0%	1.4%	0.7%	0.2%
	Control	12	100.1%	0.1%	0.5%	0.9%	0.2%
6/6	Test	12	99.7%	0.1%	3.3%	0.5%	0.0%
	Control	12	99.9%	0.0%	0.5%	0.9%	0.1%
6/7.8	Test	12	99.9%	0.0%	4.1%	1.1%	0.3%
	Control	12	100.0%	0.0%	1.0%	0.8%	0.2%
7/7	Test	5	99.8%	1.3%	10.4%	1.4%	0.0%
	Control	5	99.7%	0.0%	0.8%	1.0%	0.3%
7.8/7.8	Test	12	98.8%	3.6%	10.1%	0.9%	0.3%
	Control	12	100.4%	0.0%	1.4%	0.7%	0.2%
All Conditions	Test	65	99.5%	0.8%	6.3%	1.0%	0.2%
	Control	65	100.0%	0.0%	0.9%	0.8%	0.2%

Of over 10,000 fish recovered during testing (5,000 test fish and 5,000 controls), only 12 test fish and 8 controls died during the three- to ten-day holding period. The mortality rate was quite low even for the few fish that showed substantial levels of descaling (Table 3).

The salmon smolts used in the tests ranged from 101 to 165 mm in length. No relationship was found between fish length and injury rates. Small numbers of hatchery steelhead (188-282 mm in length), resident rainbow trout (53-122 mm) and sticklebacks (32-60 mm) were also recovered in good condition.

No operational problems were evident during the testing period. Headloss measured across the screen ranged from 0.5 ft at a penstock velocity of 4 fps to 2.0 ft at 7.8 fps. The screen appears to be largely self-cleaning, and backflushing has effectively removed any debris pinned on the screen.

EPRI studies at Elwha are continuing, and are planned to include chinook salmon and steelhead smolts in 1991.

Table 3. Mortality by Injury Class After 6-10 Days Holding.

Injury Class	Total Observed	No. of Mortalities	Mortality Rate
Descaled (>16% loss on one side)	46	4	8.7%
Scattered Scale Loss (3-16% per side)	202	0	0.0%
Patchy Scale Loss (3-16% per side)	184	2	1.1%
Other Injury	93	4	4.3%
OK (<3% scale loss)	10,611	10	0.1%
Total	11,136	20	0.2%

Conclusions

Results of the May-June 1990 tests at Elwha indicate that the Eicher Screen prototype has excellent potential for protecting downstream migrating fish. If the Eicher Screen can safely bypass other species and sizes of fish, the device may see widespread application at hydroelectric projects with penstocks. The screen's modest space requirements, low initial cost and low O&M costs constitute significant advantages over other screening systems.

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